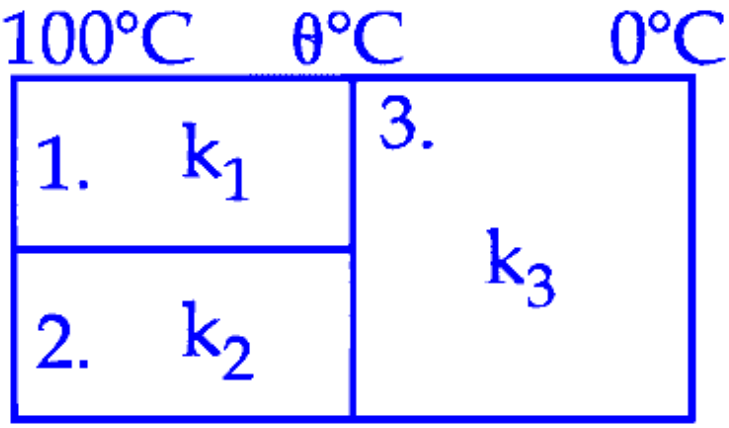
Thermodynamics

Question1

Three conductors of same length having thermal conductivity k_1, k_2 and k_3 are connected as shown in figure.



Area of cross sections of 1^{st} and 2^{nd} conductor are same and for 3^{rd} conductor it is double of the 1^{st} conductor. The temperatures are given in the figure. In steady state condition, the value of θ is_____ $^{\circ}C$.(Given : $k_1 = 60 Js^{-1} m^{-1} K^{-1}, k_2 = 120 Js^{-1} m^{-1} K^{-1}, k_3 = 135 Js^{-1} m^{-1} K^{-1}$)

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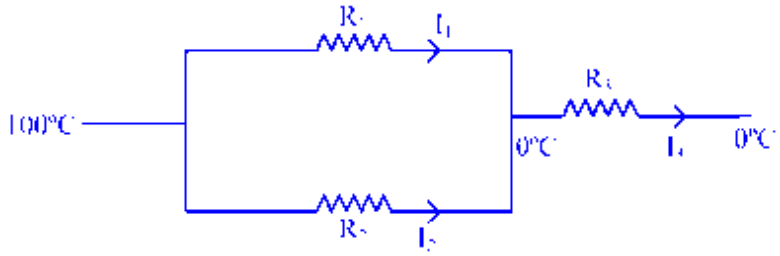
Answer: 40

Solution:



$R_1 = \frac{2L}{K_1 A}$

(As $l_1 = l_2 = l_3 = l$

$A_1 = A_2 = A/2$

$A_3 = A$)

$R_2 = \frac{2L}{K_2 A}$

$R_3 = \frac{L}{K_3 A}$

$I_1 + I_2 = I_3$

$\Rightarrow \frac{100-\theta}{\frac{2L}{K_1 A}} + \frac{100-\theta}{\frac{2L}{K_2 A}} = \frac{\theta - 0}{\frac{L}{K_3 A}}$

$\Rightarrow \frac{100-\theta}{2}(K_1 + K_2) = K_3 \theta$

$\Rightarrow 50(K_1 + K_2) = \theta \left[K_3 + \frac{K_1 + K_2}{2}\right]$

$\Rightarrow 50(60 + 120) = \theta \left[135 + \frac{60+120}{2}\right]$

$\Rightarrow 50 \times 80 = \theta(135 + 90)$

$\Rightarrow \theta = \frac{50 \times 180}{225}$

$\Rightarrow \theta = 40^\circ C$

Question2

An ideal gas initially at $0^\circ C$ temperature, is compressed suddenly to one fourth of its volume. If the ratio of specific heat at constant pressure to that at constant volume is $3/2$, the change in temperature due to the thermodynamic process is _____ K.

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Answer: 273

Solution:

We're given an ideal gas initially at $T_i = 0^\circ\mathrm{C} = 273\,\mathrm{K}$. The gas is suddenly compressed to one-fourth of its initial volume, and we are told that

$\gamma = \frac{c_p}{c_v} = \frac{3}{2}$.

For an adiabatic process (one in which there is no heat exchange), if the process were reversible, the relation between the temperature and volume would be

$T\,V^{\gamma-1} = \text{constant}$.

Even though the compression is "sudden" (and hence irreversible), the final equilibrium state of the gas is uniquely determined by its internal energy (which is a state function). That allows us to use the adiabatic relation between the initial and final states.

Here are the steps:

Write the adiabatic relation between the initial and final states:

$T_i\,V_i^{\gamma-1} = T_f\,V_f^{\gamma-1}$.

Since the gas is compressed to one-fourth of its volume, we have

$V_f = \frac{1}{4}V_i$.

Substitute this into the adiabatic relation:

$273\,V_i^{\gamma-1} = T_f\left(\frac{1}{4}V_i\right)^{\gamma-1}$.

With $\gamma = \frac{3}{2}$,

$\gamma - 1 = \frac{3}{2} - 1 = \frac{1}{2}$.

So the relation becomes:

$273\,V_i^{1/2} = T_f\left(\frac{1}{4}\right)^{1/2} V_i^{1/2}$.

Cancel the common factor $V_i^{1/2}$ (provided it is nonzero) and simplify:

$273 = T_f\left(\frac{1}{2}\right)$.

Now solve for the final temperature T_f:

$T_f = 273 \times 2 = 546\,\mathrm{K}$.

The change in temperature is then:

$\Delta T = T_f - T_i = 546 - 273 = 273\,\mathrm{K}$.

So, the change in temperature due to the thermodynamic process is $\boxed{273\,\mathrm{K}}$.

Question3

The temperature of 1 mole of an ideal monoatomic gas is increased by $50^{\circ}\mathrm{C}$ at constant pressure. The total heat added and change in internal energy are E_1 and E_2, respectively. If $\frac{E_1}{E_2} = \frac{x}{9}$ then the value of x is _____.

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Answer: 15

Solution:

$Q = n\,C_P\,\Delta T \quad$ and $\quad \Delta U = n\,C_V\,\Delta T$

For a monoatomic ideal gas, the molar specific heats are given by:

$C_V = \frac{3}{2}R \quad$ and $\quad C_P = C_V + R = \frac{5}{2}R$

Thus, the ratio of the heat added to the change in internal energy is:

$\frac{Q}{\Delta U} = \frac{C_P}{C_V} = \frac{\frac{5}{2}R}{\frac{3}{2}R} = \frac{5}{3}$

Given that:

$\frac{E_1}{E_2} = \frac{x}{9}$

We equate the two ratios:

$\frac{5}{3} = \frac{x}{9}$

Multiplying both sides by 9:

$x = \frac{5}{3} \times 9 = 15$

Thus, the value of x is **15**.

Question4

A container of fixed volume contains a gas at 27°C. To double the pressure of the gas, the temperature of gas should be raised to _____ °C.

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Answer: 327

Solution:

To solve this problem, we can use the combined gas law in terms of pressure (P) and temperature (T). For a gas with a fixed volume, the relationship is given as:

$\frac{P_1}{T_1} = \frac{P_2}{T_2}$

where:

P_1 is the initial pressure,

T_1 is the initial temperature in Kelvin,

P_2 is the final pressure,

T_2 is the final temperature in Kelvin.

Given that the initial temperature $T_1 = 27^\circ C$, we need to convert it to Kelvin:

$T_1 = 27^\circ C + 273.15 = 300.15\,\text{K}$

The final pressure P_2 is twice the initial pressure ($P_2 = 2P_1$). Substituting these values into the gas law equation gives:

$\frac{P_1}{300.15} = \frac{2P_1}{T_2}$

Solving for T_2:

Cancel P_1 from both sides:

$\frac{1}{300.15} = \frac{2}{T_2}$

Rearrange to solve for T_2:

$T_2 = 2 \times 300.15 = 600.3\,\text{K}$

Convert the final temperature back to Celsius:

$T_2 = 600.3\,\text{K} - 273.15 = 327.15^\circ C$

Therefore, to double the pressure of the gas, the temperature should be raised to approximately **327°C**.

Question5

γ_{A} is the specific heat ratio of monoatomic gas A having 3 translational degrees of freedom. γ_B is the specific heat ratio of polyatomic gas B having 3 translational, 3 rotational degrees of freedom and 1 vibrational mode. If $\frac{\gamma_A}{\gamma_B}=\left(1+\frac{1}{n}\right)$, then the value of n is _____ .

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Answer: 3

Solution:

To determine the value of n, we start by considering the specific heat ratios for gases A and B.

For gas A, which is monoatomic with 3 translational degrees of freedom:

The degrees of freedom, f_A, is 3.

Therefore, $\gamma_A = \frac{f_A+2}{f_A} = \frac{3+2}{3} = \frac{5}{3}$.

For gas B, which is polyatomic with 3 translational, 3 rotational degrees of freedom, and 1 vibrational mode:

The total degrees of freedom, f_B, is $3 + 3 + 2 \times 1 = 8$ (since one vibrational mode contributes 2 degrees of freedom: 1 kinetic + 1 potential).

Therefore, $\gamma_B = \frac{f_B+2}{f_B} = \frac{8+2}{8} = \frac{10}{8} = \frac{5}{4}$.

Now, the relation given is:

$\frac{\gamma_A}{\gamma_B} = \left(1+\frac{1}{n}\right)$

Substitute the values of γ_A and γ_B:

$\frac{\frac{5}{3}}{\frac{5}{4}} = \frac{5}{3} \times \frac{4}{5} = \frac{20}{15} = \frac{4}{3}$

Equating to the given form:

$\frac{4}{3} = 1 + \frac{1}{n}$

Thus, we have:

$\frac{4}{3} - 1 = \frac{1}{n}$

$\frac{1}{3} = \frac{1}{n}$

Solving for n:

$n = 3$

Hence, the value of n is 3.

Question6

The internal energy of air in $4\ \mathrm{m} \times 4\ \mathrm{m} \times 3\ \mathrm{m}$ sized room at 1 atmospheric pressure will be_____$\times 10^6$ J

(Consider air as diatomic molecule)

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Answer: 12

Solution:

To determine the internal energy of the air in a room that measures $4\,\mathrm{m} \times 4\,\mathrm{m} \times 3\,\mathrm{m}$ at 1 atmospheric pressure, we can follow these steps using the properties of a diatomic gas:

The volume of the room, V, is calculated as:

$V = 4\,\mathrm{m} \times 4\,\mathrm{m} \times 3\,\mathrm{m} = 48\,\mathrm{m}^3$

For a diatomic gas like air, the internal energy U is given by the formula:

$U = nC_vT = n\frac{5RT}{2}$

Where:

n is the number of moles,

C_v is the molar heat capacity at constant volume,

R is the ideal gas constant, and

T is the temperature in Kelvin.

Using the ideal gas law, $PV = nRT$, we can substitute for nRT:

$nRT = PV$

Therefore, the internal energy U becomes:

$U = \frac{5}{2}PV$

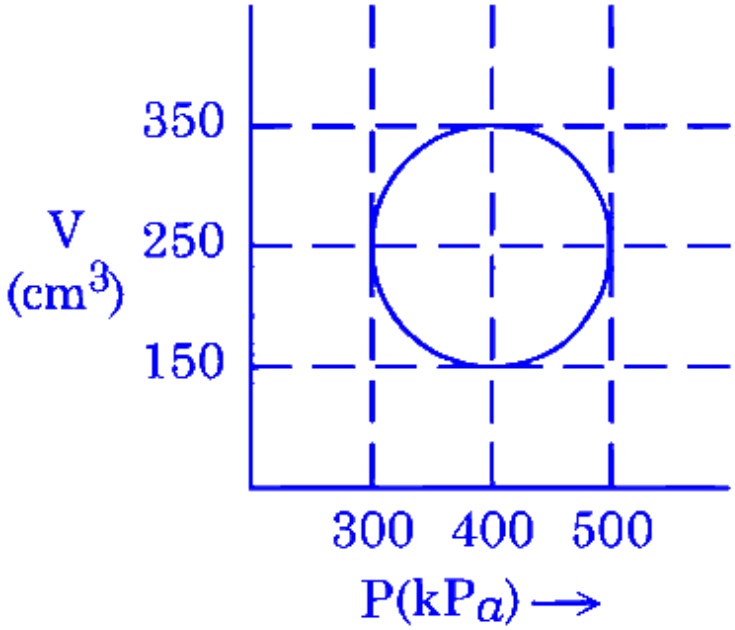
Substituting the given values for atmospheric pressure $P = 10^5\,\mathrm{Pa}$ (1 atm) and volume $V = 48\,\mathrm{m}^3$:

$U = \frac{5}{2} \times 10^5\,\text{Pa} \times 48\,\text{m}^3 = 12 \times 10^6\,\text{J}$

Thus, the internal energy of the air in the room is 12×10^6 J.

Question7

An ideal gas has undergone through the cyclic process as shown in the figure. Work done by the gas in the entire cycle is _____ $\times 10^{-1}$ J.(Take $\pi = 3.14$)



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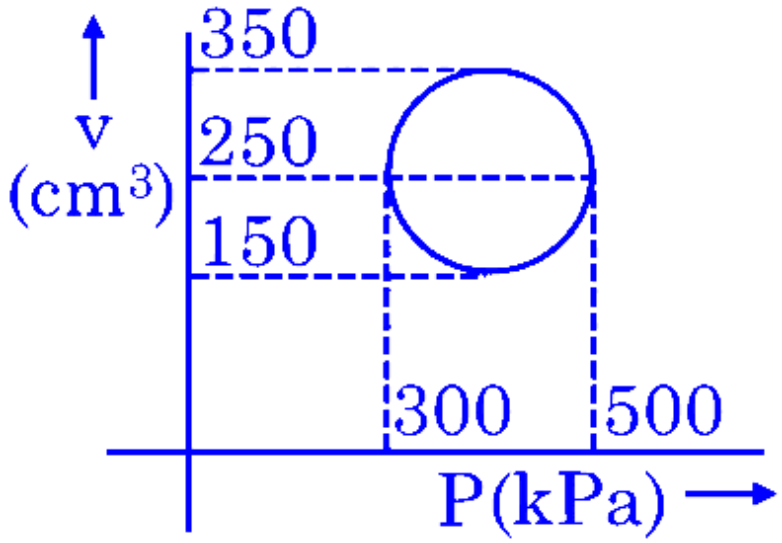
Answer: 314

Solution:



Area of circle, $W = \frac{\pi}{4} d_1 d_2$

$\mathrm{W} = \frac{\pi}{4}(500 - 300) \times 10^3 (350 - 150) \times 10^{-6}$

$\mathrm{W} = 31.4 \mathrm{Joule}$

$\mathrm{W} = 314 \times 10^{-1} \mathrm{Joule}$

Question8

A wire of length 10 cm and diameter 0.5 mm is used in a bulb. The temperature of the wire is $1727^{\circ}\mathrm{C}$ and power radiated by the wire is 94.2 W . Its emissivity is $\frac{x}{8}$ where $x =$ _____.

(Given $\sigma = 6.0 \times 10^{-8}\ \mathrm{W\ m^{-2}\ K^{-4}}, \pi = 3.14$ and assume that the emissivity of wire material is same at all wavelength.)

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Answer: 5

Solution:

To determine the emissivity (ε) of the wire used in the bulb, we start with the given parameters and the formula for power radiated by a black body:

Length of the wire (L): 10 cm = 0.1 m

Diameter of the wire (d): 0.5 mm = 0.0005 m

Temperature of the wire (T): $1727^\circ\text{C} = 2000\text{K}$

Power radiated (P): 94.2 W

The power radiated by the wire can be expressed as:

$P = \varepsilon\sigma AT^4$

Where:

σ is the Stefan-Boltzmann constant ($6.0 \times 10^{-8}\ \text{W m}^{-2}\ \text{K}^{-4}$)

A is the surface area of the wire, calculated using the formula for the surface area of a cylinder: $A = \pi dL$

Substituting the given values into the formula:

$94.2 = \varepsilon \times (6 \times 10^{-8}) \times (3.14 \times 0.0005 \times 0.1) \times (2000)^4$

Simplifying the expression inside the parentheses:

$94.2 = \varepsilon \times (6 \times 10^{-8}) \times 3.14 \times 0.0005 \times 0.1 \times (2000)^4$

On solving for ε:

$\varepsilon = \frac{94.2}{[(6\times10^{-8})\times3.14\times0.0005\times0.1\times(2000)^4]}$

Given that ε is $\frac{x}{8}$, evaluating this expression provides the value of $x = 5$. Thus, the emissivity ε is $\frac{5}{8}$.

Question9

Two cylindrical rods A and B made of different materials, are joined in a straight line. The ratios of lengths, radii and thermal conductivites of these rods are: $\frac{\mathrm{L_A}}{\mathrm{L_B}} = \frac{1}{2}, \frac{\mathrm{r_A}}{\mathrm{r_B}} = 2$ and $\frac{\mathrm{K_A}}{\mathrm{K_B}} = \frac{1}{2}$. The free ends of rods A and B are maintained at 400 K , 200 K , respectively. The temperature of rods interface is _____ K, when equilibrium is established.

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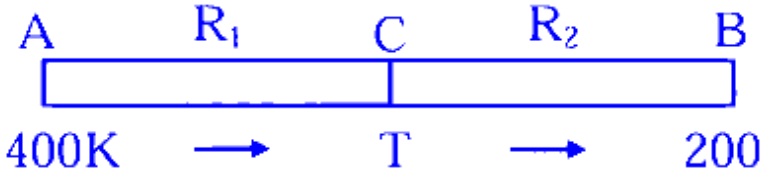
Answer: 360

Solution:



$$R_1 = \frac{\ell_1}{K_1 A_1}, R_2 = \frac{\ell_2}{K_2 A_2}$$

$$\frac{dQ}{dt} = \frac{\Delta T}{R}$$

$$\left(\frac{dQ}{dt}\right)_1 = \left(\frac{dQ}{\mu}\right)_2$$

$$\frac{400 - T}{R_1} = \frac{T - 200}{R_2}$$

$$\frac{400 - T}{T - 200} = \frac{R_1}{R_2} = \left(\frac{\ell_1}{\ell_2}\right)\left(\frac{r_2}{r_1}\right)^2 \times \frac{K_2}{K_1}$$

$$= \frac{1}{2} \times \left(\frac{1}{2}\right)^2 \times 2$$

$$= \left(\frac{1}{4}\right)$$

$$\frac{400 - T}{T - 200} = \frac{1}{4}$$

$$1600 - 4T = T - 200$$

$$5T = 1800$$

$$T = 360\ K$$

Question10

An amount of ice of mass 10^{-3} kg and temperature $-10^{\circ}C$ is transformed to vapour of temperature $110^{\circ}C$ by applying heat. The total amount of work required for this conversion is, (Take, specific heat of ice $= 2100 Jkg^{-1}\ K^{-1}$, specific heat of water $= 4180 Jkg^{-1}\ K^{-1}$, specific heat of steam $= 1920 Jkg^{-1}\ K^{-1}$, Latent heat of ice $= 3.35 \times 10^5 Jkg^{-1}$ and Latent heat of steam $= 2.25 \times 10^6$ Jkg^{-1})

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Options:

A. 3022 J

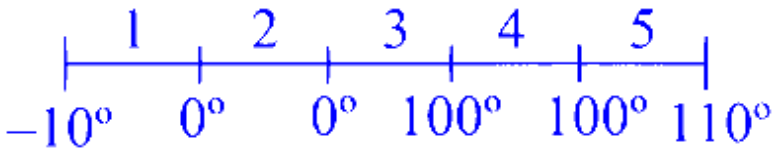
B. 3043 J

C. 3003 J

D. 3024 J

Answer: B

Solution:



$\Delta Q_1 = ms_i\Delta T_2$, $\Delta Q_2 = mL_i$

$\Delta Q_3 = mS_w\Delta T_3$, $\Delta Q_4 = mL_s$, $\Delta Q_5 = mS_s\Delta T_5$

$\Delta Q_{net} = m(S_i\Delta T_1 + L_i + S_w\Delta T_3 + L_s + S_s\Delta T_s)$

$= 10^{-3}(2100 \times 10 + 335000 + 4180 \times 100 + 2250000 + 1920 \times 10)$

$= 10^{-3}(3043200) = 3043.2\,J$

So, $\Delta Q_{net} \approx 3043\,J$

Question11

Two spherical bodies of same materials having radii 0.2 m and 0.8 m are placed in same atmosphere. The temperature of the smaller body is 800 K and temperature of the bigger body is 400 K . If the energy radiated from the smaller body is E, the energy radiated from the bigger body is (assume, effect of the surrounding temperature to be negligible),

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Options:

A. 64 E

B. 16 E

C. E

D. 256 E

Answer: C

Solution:

To determine the energy radiated by two spherical bodies, both made of the same material but with different radii and temperatures, we can use the Stefan-Boltzmann law. This law states that the energy radiated by a black body per unit time is proportional to the product of the surface area A and the fourth power of its temperature T.

The formula for power P is given by:

$P = \sigma e A T^4$

Where:

σ is the Stefan-Boltzmann constant

e is the emissivity of the material

A is the surface area of the sphere

T is the temperature in Kelvin

Expressing this relationship as a proportionality:

$P \propto A T^4$

For a sphere, the surface area A is:

$A = 4\pi R^2$

Hence, the power radiated is proportional to:

$P \propto R^2 T^4$

For two bodies with radii R_1 and R_2, and temperatures T_1 and T_2, the ratio of their powers is:

$\frac{P_1}{P_2} = \left(\frac{R_1}{R_2}\right)^2 \left(\frac{T_1}{T_2}\right)^4$

Given:

$R_1 = 0.2\,\text{m}, T_1 = 800\,\text{K}$

$R_2 = 0.8\,\text{m}, T_2 = 400\,\text{K}$

Substituting into the formula:

$\frac{E}{E'} = \left(\frac{0.2}{0.8}\right)^2 \left(\frac{800}{400}\right)^4$

Calculating each part:

$\left(\frac{0.2}{0.8}\right)^2 = \left(\frac{1}{4}\right)^2 = \frac{1}{16}$

$\left(\frac{800}{400}\right)^4 = 2^4 = 16$

Combining these calculations:

$\frac{E}{E'} = \frac{1}{16} \times 16 = 1$

This implies that the energy radiated by the bigger body E' equals the energy radiated by the smaller body E. Thus, $E' = E$.

Question12

For a diatomic gas, if $\gamma_1 = \left(\frac{Cp}{Cv}\right)$ for rigid molecules and $\gamma_2 = \left(\frac{Cp}{Cv}\right)$ for another diatomic molecules, but also having vibrational modes. Then, which one of the following options is correct? (Cp and Cv are specific heats of the gas at constant pressure and volume)

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Options:

A. $\gamma_2 < \gamma_1$

B. $\gamma_2 > \gamma_1$

C. $\gamma_2 = \gamma_1$

D. $2\gamma_2 = \gamma_1$

Answer: A

Solution:

Let's analyze the problem step by step:

For a rigid diatomic molecule (without vibrational modes):

Degrees of freedom:

Translation: 3

Rotation: 2

Total: 5

The molar specific heat at constant volume is given by:

$C_v = \frac{5}{2}R$

At constant pressure, it is:

$C_p = C_v + R = \frac{5}{2}R + R = \frac{7}{2}R$

Therefore, the ratio is:

$\gamma_1 = \frac{C_p}{C_v} = \frac{\frac{7}{2}R}{\frac{5}{2}R} = \frac{7}{5} \approx 1.4$

For the diatomic molecule that also has vibrational modes (assuming the vibrational mode is fully excited):

Additional vibrational mode contributions:

Each vibrational mode contributes 2 degrees of freedom (one kinetic and one potential).

Therefore, the degrees of freedom become:

$3 \text{ (translation)} + 2 \text{ (rotation)} + 2 \text{ (vibration)} = 7$

The molar specific heat at constant volume now is:

$C_v = \frac{7}{2}R$

And at constant pressure:

$C_p = C_v + R = \frac{7}{2}R + R = \frac{9}{2}R$

Thus, the ratio is:

$\gamma_2 = \frac{C_p}{C_v} = \frac{\frac{9}{2}R}{\frac{7}{2}R} = \frac{9}{7} \approx 1.2857$

Comparison:

For the rigid molecule, $\gamma_1 \approx 1.4$.

For the molecule with vibrational modes, $\gamma_2 \approx 1.2857$.

Clearly, $\gamma_2 < \gamma_1$.

Therefore, the correct option is:

Option A: $\gamma_2 < \gamma_1$

Question13

Given are statements for certain thermodynamic variables,

(A) Internal energy, volume (V) and mass (M) are extensive variables.

(B) Pressure (P), temperature (T) and density (ρ) are intensive variables.

(C) Volume (V), temperature (T) and density (ρ) are intensive variables.

(D) Mass (M), temperature (T) and internal energy are extensive variables.

Choose the correct answer from the options given below :

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Options:

A. (C) and (D) Only

B. (A) and (B) Only

C. (D) and (A) Only

D. (B) and (C) Only

Answer: B

Solution:

Check Statement (A):

"Internal energy (U), volume (V), and mass (M) are extensive variables."

Internal energy is extensive.

Volume is extensive.

Mass is extensive.

Hence, statement (A) is **correct**.

Check Statement (B):

"Pressure (P), temperature (T), and density (ρ) are intensive variables."

Pressure is intensive.

Temperature is intensive.

Density is intensive.

Hence, statement (B) is **correct**.

Check Statement (C):

“Volume (V), temperature (T), and density (ρ) are intensive variables.”

Volume is **not** intensive; it is an extensive property.

(T) and (ρ) are indeed intensive.

Since volume is miscategorized here, (C) is **incorrect**.

Check Statement (D):

“Mass (M), temperature (T), and internal energy are extensive variables.”

Mass is extensive.

Temperature is **not** extensive (it is intensive).

Internal energy is extensive.

Because temperature is miscategorized, (D) is **incorrect**.

Only **(A)** and **(B)** are correct statements.

Therefore, the correct choice is:

Option B: (A) and (B) Only.

Question14

A gun fires a lead bullet of temperature 300 K into a wooden block. The bullet having melting temperature of 600 K penetrates into the block and melts down. If the total heat required for the process is 625 J , then the mass of the bullet is _____ grams.(Latent heat of fusion of lead $= 2.5 \times 10^4 \mathrm{JKg}^{-1}$ and specific heat capacity of lead $= 125 \mathrm{JKg}^{-1}\ \mathrm{K}^{-1}$)

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Options:

A. 20

B. 15

C. 5

D. 10

Answer: D

Solution:

Let's determine the mass step by step:

The bullet is heated from 300 K to 600 K, so the increase in temperature is:

$\Delta T = 600\,\text{K} - 300\,\text{K} = 300\,\text{K}.$

The heat required to raise the temperature of the bullet (using the specific heat capacity of lead) is:

$Q_1 = m \times c \times \Delta T = m \times 125\,\text{J/kg K} \times 300\,\text{K} = 37500\,m\,\text{J},$

where m is the mass in kilograms.

After reaching 600 K, the bullet melts. The heat required for the phase change (melting) is given by:

$Q_2 = m \times L = m \times 2.5 \times 10^4\,\text{J/kg} = 25000\,m\,\text{J}.$

The total heat required for the process is:

$Q = Q_1 + Q_2 = 37500\,m + 25000\,m = 62500\,m\,\text{J}.$

We are given that the total heat is 625 J, so:

$62500\,m = 625.$

Solving for m:

$m = \frac{625}{62500} = 0.01\,\text{kg}.$

Finally, converting the mass from kilograms to grams:

$0.01\,\text{kg} = 0.01 \times 1000\,\text{g} = 10\,\text{g}.$

Thus, the mass of the bullet is 10 grams. This corresponds to Option D.

Question15

Match the List - I with List - II

	List - I		List - II
(A)	Pressure varies inversely with volume of an ideal gas.	(I)	Adiabatic process
(B)	Heat absorbed goes partly to increase internal energy and partly to do work.	(II)	Isochoric process

	List - I		List - II
(C)	Heat is neither absorbed nor released by a system.	(III)	Isothermal process
(D)	No work is done on or by a gas.	(IV)	Isobaric process

Choose the correct answer from the options given below:

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Options:

A. A-I, B-III, C-II, D-IV

B. A-I, B-IV, C-II, D-III

C. A-III, B-I, C-IV, D-II

D. A-III, B-IV, C-I, D-II

Answer: D

Solution:

Let's analyze each statement step by step:

For (A): “Pressure varies inversely with volume of an ideal gas.”

At constant temperature (isothermal process), Boyle's law applies:

$PV =$ constant.

Thus, pressure and volume have an inverse relationship.

Hence, (A) corresponds to the Isothermal process, which is (III).

For (B): “Heat absorbed goes partly to increase internal energy and partly to do work.”

In a constant pressure (isobaric) process, when heat is supplied, part of it is used to do work (expansion, for example) and the rest increases the internal energy.

Therefore, (B) matches with the Isobaric process, which is (IV).

For (C): “Heat is neither absorbed nor released by a system.”

This implies that the process is adiabatic (no heat exchange).

Thus, (C) matches with the Adiabatic process, which is (I).

For (D): “No work is done on or by a gas.”

Work done by a gas is given by $W = P\Delta V$.

If the volume does not change (constant volume), then no work is done.

So, (D) identifies with the Isochoric process, which is (II).

Putting it all together:

(A) → (III) Isothermal process

(B) → (IV) Isobaric process

(C) → (I) Adiabatic process

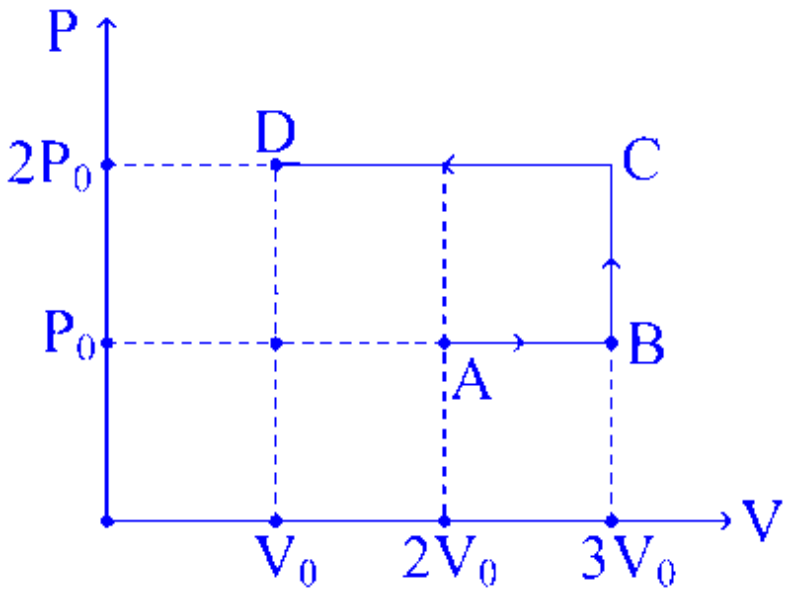
(D) → (II) Isochoric process

Thus, the correct answer is:

Option D

A-III, B-IV, C-I, D-II.

Question16



Using the given $P - V$ diagram, the work done by an ideal gas along the path $ABCD$ is :

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Options:

A. $3P_0\ V_0$

B. $-3\mathrm{P}_0\ \mathrm{V}_0$

C. $-4\mathrm{P}_0\ \mathrm{V}_0$

D. $4\mathrm{P}_0\ \mathrm{V}_0$

Answer: B

Solution:

To find the work done by an ideal gas along the path $ABCD$ on the given $P-V$ diagram, we calculate the work done on each segment individually and then sum them up.

Segment AB: The work is given by $\mathrm{w}_{AB} = P_0 \times V_0$, contributing P_0V_0.

Segment BC: No volume change occurs along this path, resulting in zero work: $\mathrm{w}_{BC} = 0$.

Segment CD: The gas compresses, performing negative work: $\mathrm{w}_{CD} = -(2P_0 \times 2V_0) = -4P_0V_0$.

Adding the work done in each segment:

$$\begin{aligned}\mathrm{w}_{ABCD} &= \mathrm{w}_{AB} + \mathrm{w}_{BC} + \mathrm{w}_{CD} \\ &= P_0V_0 + 0 - 4P_0V_0 \\ &= -3P_0V_0\end{aligned}$$

Thus, the total work done by the gas along the path $ABCD$ is $-3P_0V_0$.

Question17

Water of mass m gram is slowly heated to increase the temperature from T_1 to T_γ. The change in entropy of the water, given specific heat of water is $1\mathrm{Jkg}^{-1}\ \mathrm{K}^{-1}$, is :

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Options:

A. $\mathrm{m}\left(\mathrm{T}_2-\mathrm{T}_1\right)$

B. zero

C. $\mathrm{m} \ln \left(\frac{\mathrm{T}_1}{\mathrm{T}_2}\right)$

D. $\mathrm{m} \ln \left(\frac{\mathrm{T}_2}{\mathrm{T}_1}\right)$

Answer: D

Solution:

To determine the change in entropy when water is heated from temperature T_1 to T_2 (here, T_γ is equivalent to T_2), we use the definition of entropy change for a reversible process:

$\Delta S = \int_{T_1}^{T_2} \frac{dQ}{T}$

Since the water is being heated slowly, the process is reversible, and the heat added is given by:

$dQ = mc\,dT$

where:

• m is the mass of the water,

• c is the specific heat capacity (given as $1\,\mathrm{J\,kg^{-1}\,K^{-1}}$).

Substitute dQ into the integral:

$\Delta S = \int_{T_1}^{T_2} \frac{mc\,dT}{T} = mc \int_{T_1}^{T_2} \frac{dT}{T}.$

Since $c = 1$, the equation simplifies to:

$\Delta S = m \int_{T_1}^{T_2} \frac{dT}{T}.$

Evaluating the integral, we have:

$\int_{T_1}^{T_2} \frac{dT}{T} = \ln T \Big|_{T_1}^{T_2} = \ln \left(\frac{T_2}{T_1}\right).$

Thus, the change in entropy is:

$\Delta S = m \ln \left(\frac{T_2}{T_1}\right).$

Comparing with the options provided, the correct answer is:

Option D: $m \ln \left(\frac{T_2}{T_1}\right)$.

Question18

An ideal gas goes from an initial state to final state. During the process, the pressure of gas increases linearly with temperature.

A. The work done by gas during the process is zero.

B. The heat added to gas is different from change in its internal energy.

C. The volume of the gas is increased.

D. The internal energy of the gas is increased.

E. The process is isochoric (constant volume process)

Choose the correct answer from the options given below:

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Options:

A. A, C Only

B. A, D, E Only

C. E Only

D. A, B, C, D Only

Answer: B

Solution:

For an ideal gas, the equation of state is given by

$pV = nRT$.

If during a process the pressure increases linearly with temperature (i.e., $p \propto T$), then from the ideal gas law (with a fixed amount of gas, n, and with the gas constant, R), it follows that

$\frac{p}{T} = \frac{nR}{V}$.

Since nR is constant, a linear relationship between p and T implies that $\frac{p}{T}$ remains constant throughout the process. This can only be true if the volume V is constant. Hence, the process is isochoric.

For an isochoric (constant volume) process:

The work done by the gas is given by

$W = \int p\, dV$,

and since $dV = 0$, we have $W = 0$. (Statement A is true.)

The internal energy change for an ideal gas depends only on temperature:

$\Delta U = nC_V \Delta T$.

If the temperature increases, then $\Delta U > 0$. (Statement D is true.)

For an isochoric process, no expansion work is done, so any heat added goes entirely into increasing the internal energy. This means the heat added is not different from the change in internal energy (in fact, $Q = \Delta U$). (Statement B is false.)

Since the process is isochoric, the volume does not change (and certainly is not increased). (Statement C is false, and Statement E stating it is isochoric is true.)

Thus, the correct true statements are A, D, and E.

Question19

Which of the following figure represents the relation between Celsius and Fahrenheit temperatures?

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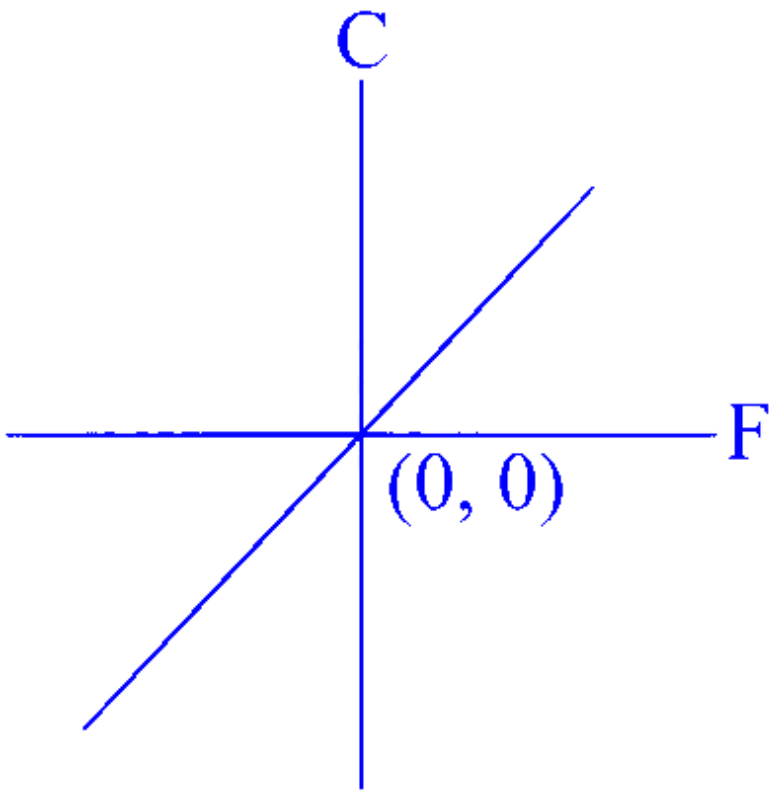
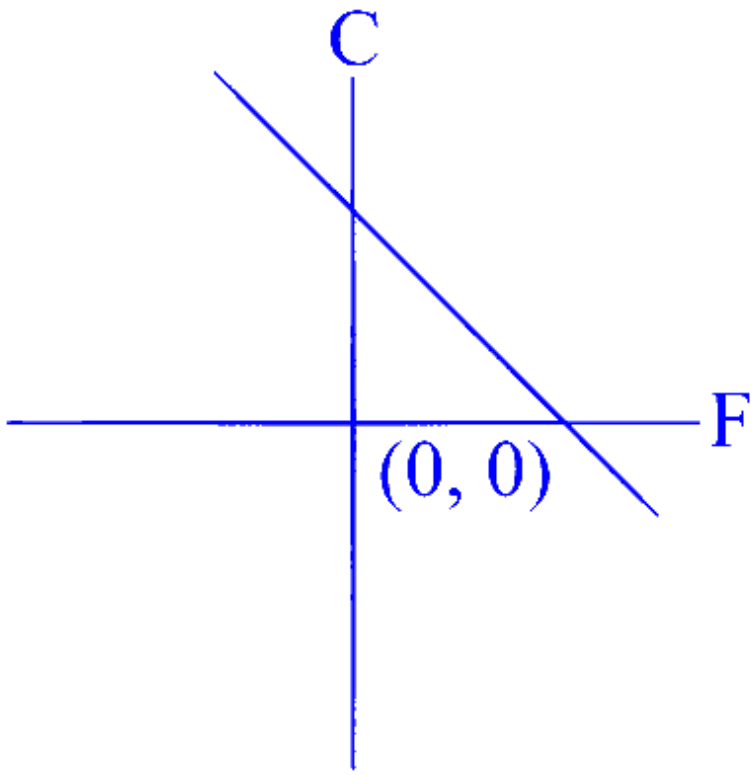
Options:

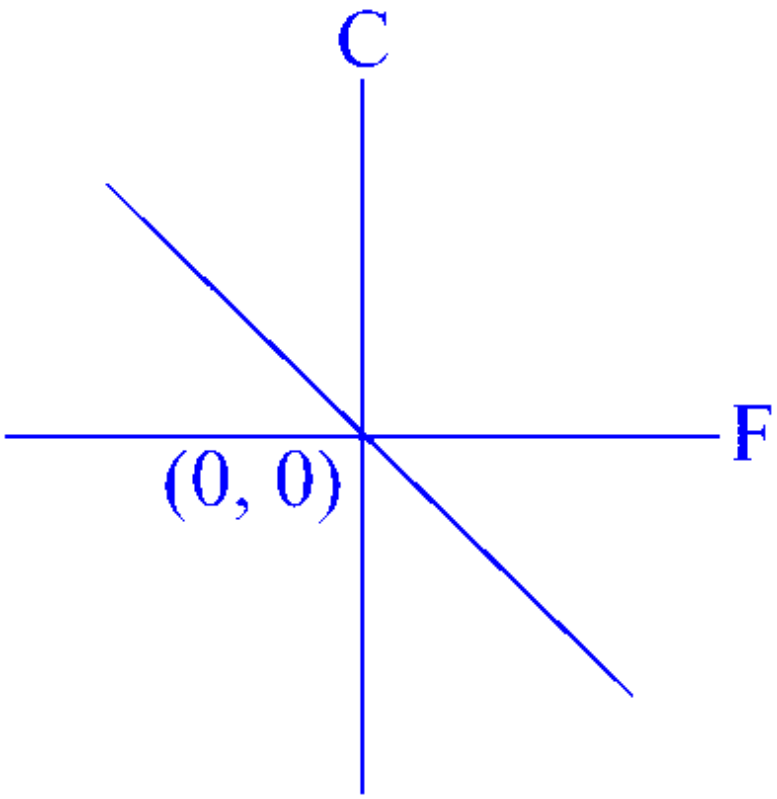
A.



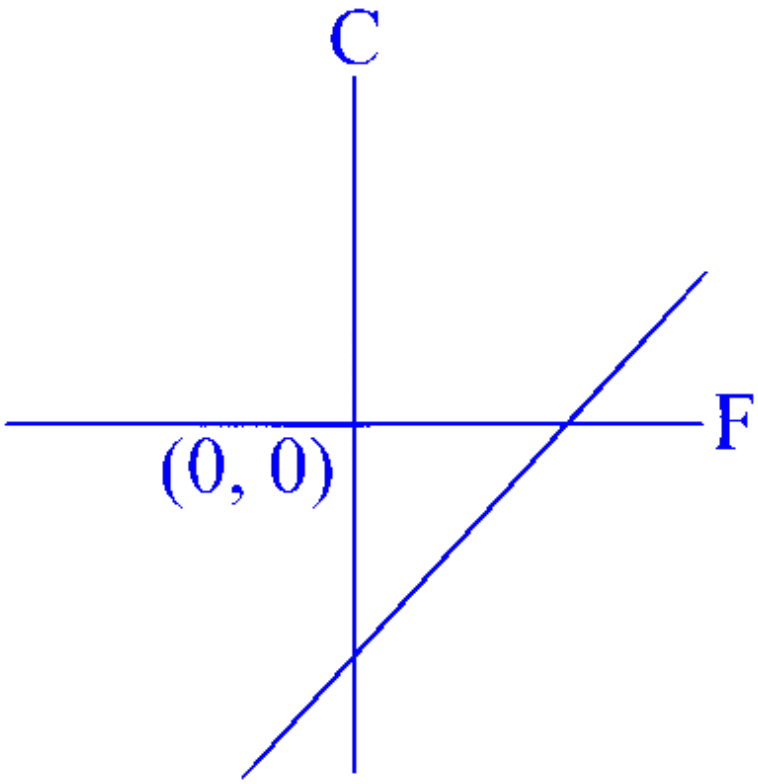
B.



C.



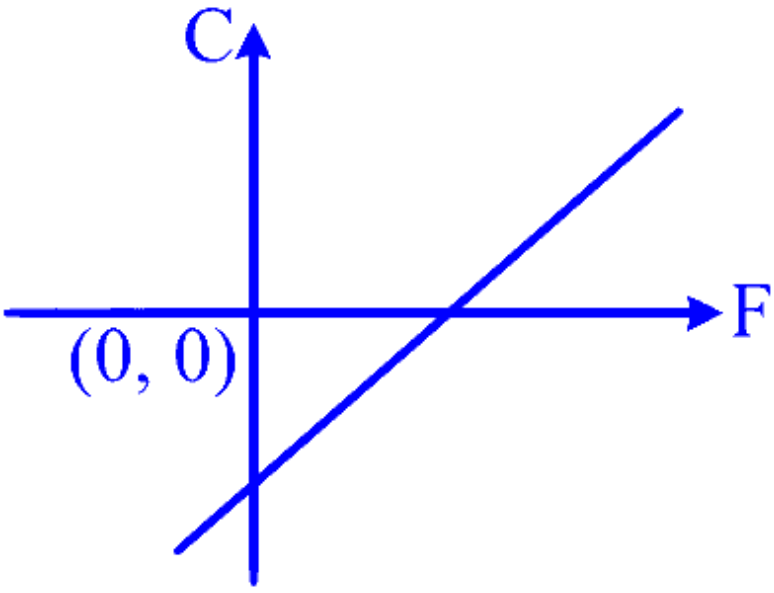
D.



Answer: D

Solution:

$\frac{C}{5} = \frac{F-32}{9} \Rightarrow C = \frac{5F}{9} - \frac{160}{9}$



Question20

Given below are two statements. One is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A) : In an insulated container, a gas is adiabatically shrunk to half of its initial volume. The temperature of the gas decreases.

Reason (R) : Free expansion of an ideal gas is an irreversible and an adiabatic process.

In the light of the above statements, choose the correct answer from the options given below :

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Options:

A. Both $(\mathbf{A})$ and $(\mathbf{R})$ are true and $(\mathbf{R})$ is the correct explanation of $(\mathbf{A})$

B. Both (A) and (R) are true but (R) is NOT the correct explanation of (A)

C. (A) is false but (R) is true

D. (A) is true but $(\mathbf{R})$ is false

Answer: C

Solution:

Let's analyze both statements step by step.

Assertion (A): "In an insulated container, a gas is adiabatically shrunk to half of its initial volume. The temperature of the gas decreases."

- In an adiabatic process, no heat is exchanged with the surroundings.
- For a reversible adiabatic (compression) process, the relationship between temperature and volume is given by

  $TV^{\gamma-1} = \text{constant},$

  where γ is the heat capacity ratio (greater than 1).
- If the volume is reduced from V to $V/2$, then

  $T_{\text{final}} = T_{\text{initial}} \left(\frac{V}{V/2}\right)^{\gamma-1} = T_{\text{initial}} (2)^{\gamma-1}.$
- Since $(2)^{\gamma-1} > 1$, the final temperature is higher than the initial temperature.
- Therefore, the assertion that the temperature decreases is incorrect.

Reason (R): "Free expansion of an ideal gas is an irreversible and an adiabatic process."

- In a free expansion, the gas expands into a vacuum without doing any work on the surroundings.
- Since the container is insulated, no heat is exchanged, making it adiabatic.
- However, the process is inherently irreversible due to the spontaneous expansion and mixing of states.
- Thus, this statement is true.

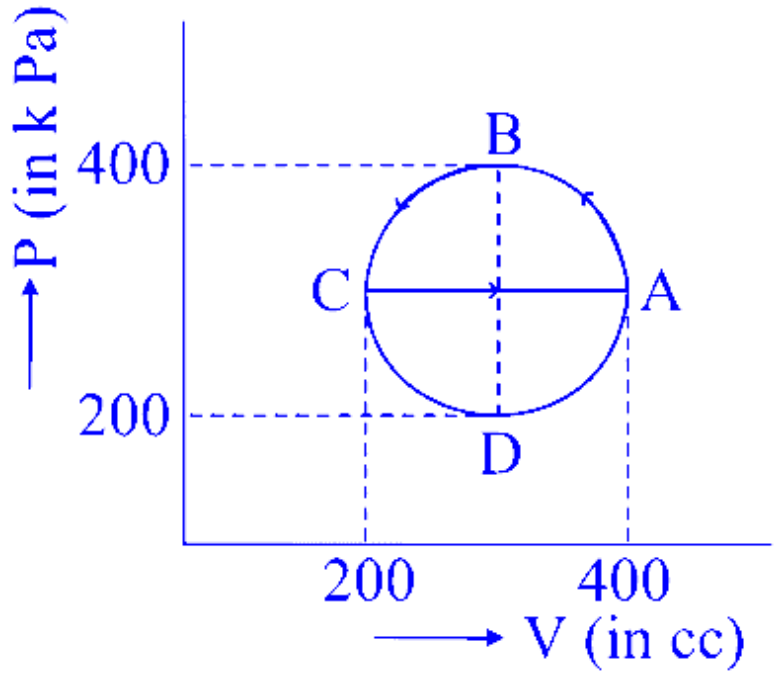
Since Assertion (A) is false and Reason (R) is true (but the reason does not explain the false assertion about temperature change during compression), the correct answer is:

Option C

(A) is false but (R) is true.

Question21

The magnitude of heat exchanged by a system for the given cyclic process ABCA (as shown in figure) is (in SI unit) :



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Options:

A. zero

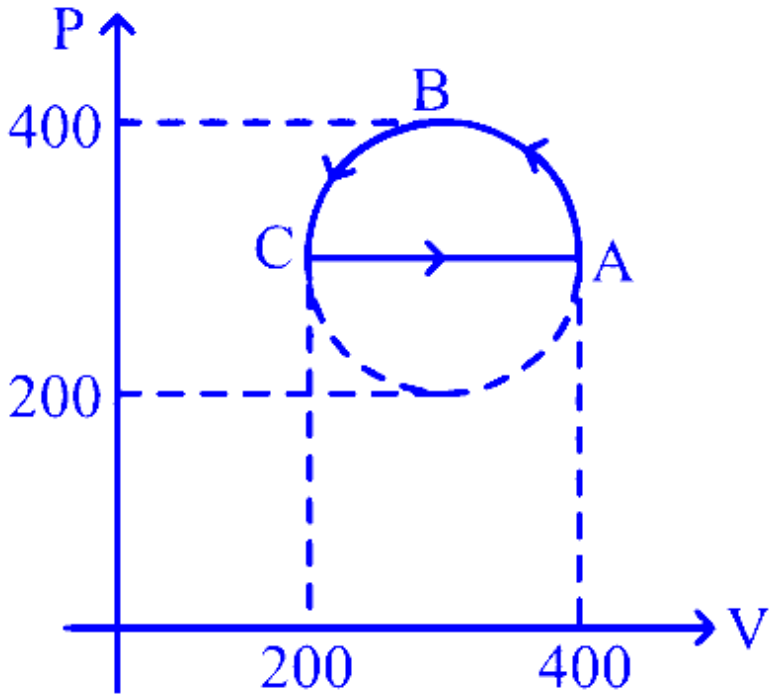
B. 40π

C. 5π

D. 10π

Answer: C

Solution:



$$W = \frac{1}{2}\pi R^2$$
$$= \frac{1}{2} \times \pi \times \left(\frac{200}{2} \times 10^3\right) \times \frac{200}{2} \times 10^{-6}$$
$$= \frac{10\pi}{2} = 5\pi \text{ J}$$

Question22

The temperature of a body in air falls from $40^\circ C$ to $24^\circ C$ in 4 minutes. The temperature of the air is $16^\circ C$. The temperature of the body in the next 4 minutes will be :

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Options:

A. $\frac{28}{3}^{\circ}\mathrm{C}$

B. $\frac{56}{3}^{\circ}\mathrm{C}$

C. $\frac{42}{3}^{\circ}\mathrm{C}$

D. $\frac{14}{3}^{\circ}\mathrm{C}$

Answer: B

Solution:

$$\frac{\mathrm{T_2}-\mathrm{T_1}}{\mathrm{t}}=\mathrm{K}\left[\mathrm{T_{avg}}\ -\mathrm{T_s}\right]$$
$$\mathrm{T_1}=24^{\circ}\mathrm{C};\mathrm{T_2}=40^{\circ}\mathrm{C},\mathrm{t}=4,\ \mathrm{T_s}=16^{\circ}\mathrm{C}$$
$$\frac{40-24}{4}=\mathrm{K}[32-16]$$
$$\mathrm{K}=\frac{4}{16}=\frac{1}{4}$$
$$\text{Now}\ \frac{24-\mathrm{T}}{4}=\mathrm{K}\left[\frac{\mathrm{T}+24}{2}-16\right]$$
$$24-\mathrm{T}=\frac{\mathrm{T}-16}{2}+16$$
$$\frac{3\,\mathrm{T}}{2}=28$$
$$\mathrm{T}=\frac{56}{3}\mathrm{C}$$

Question23

A Carnot engine (E) is working between two temperatures 473 K and 273 K . In a new system two engines - engine E_1 works between 473 K to 373 K and engine E_2 works between 373 K to 273 K .If η_{12}, η_1 and η_2 are the efficiencies of the engines E, E_1 and E_2, respectively, then

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Options:

A. $\eta_{12}=\eta_1\eta_2$

B. $\eta_{12}=\eta_1+\eta_2$

C. $\eta_{12} \geq \eta_1 + \eta_2$

D. $\eta_{12} < \eta_1 + \eta_2$

Answer: D

Solution:

We know, efficiency of a carnot engine, η or $e = 1 - \frac{T_C}{T_H}$

where, T_C = temperature of cold sink

T_H = temperature of hot source

So, $\eta_{12} = 1 - \frac{273}{473} = \frac{200}{473} = 0.423$

$\eta_1 = 1 - \frac{373}{473} = \frac{100}{473} = 0.211$

$\eta_2 = 1 - \frac{273}{373} = \frac{100}{373} = 0.268$

Here, $\eta_1 + \eta_2 = 0.211 + 0.268 = 0.479 > 0.423$

So, $\eta_{12} < \eta_1 + \eta_2$

Question24

For a particular ideal gas which of the following graphs represents the variation of mean squared velocity of the gas molecules with temperature?

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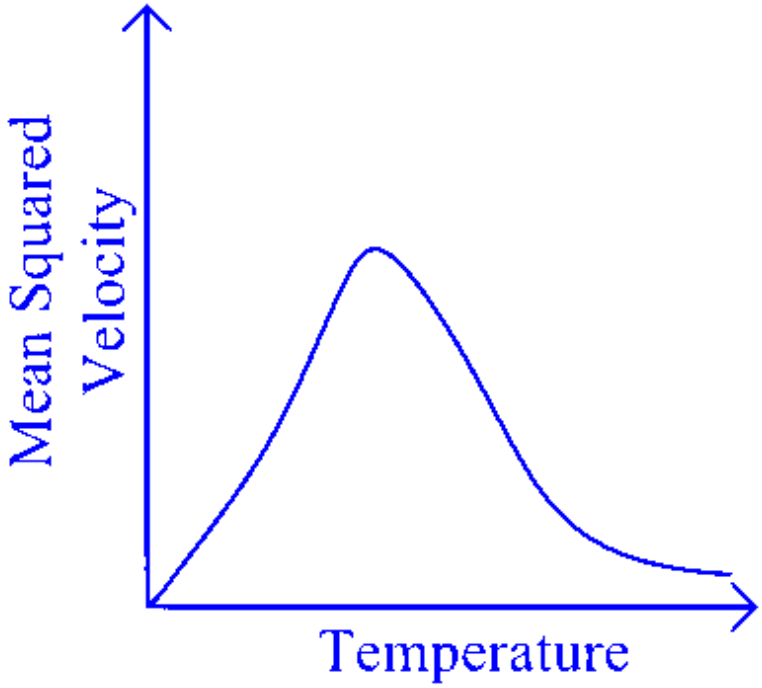
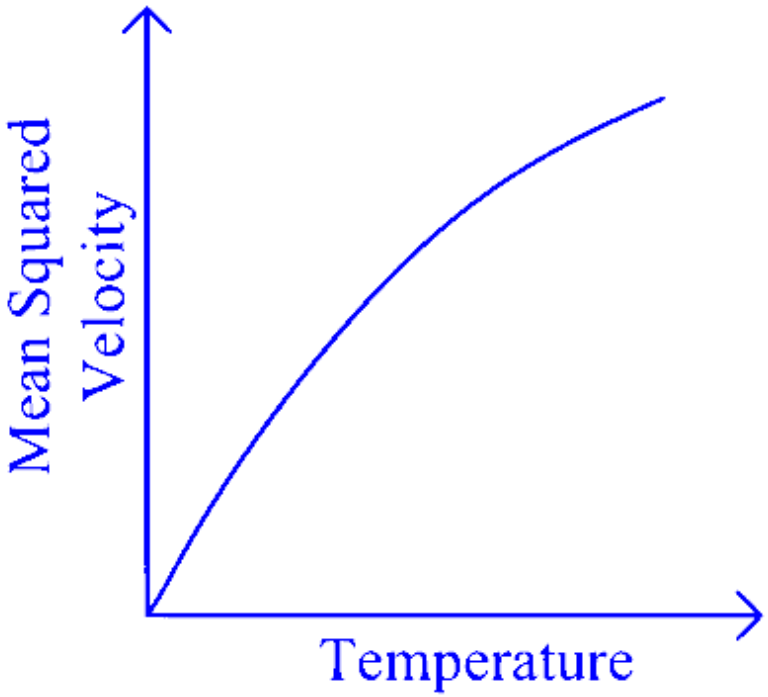
Options:

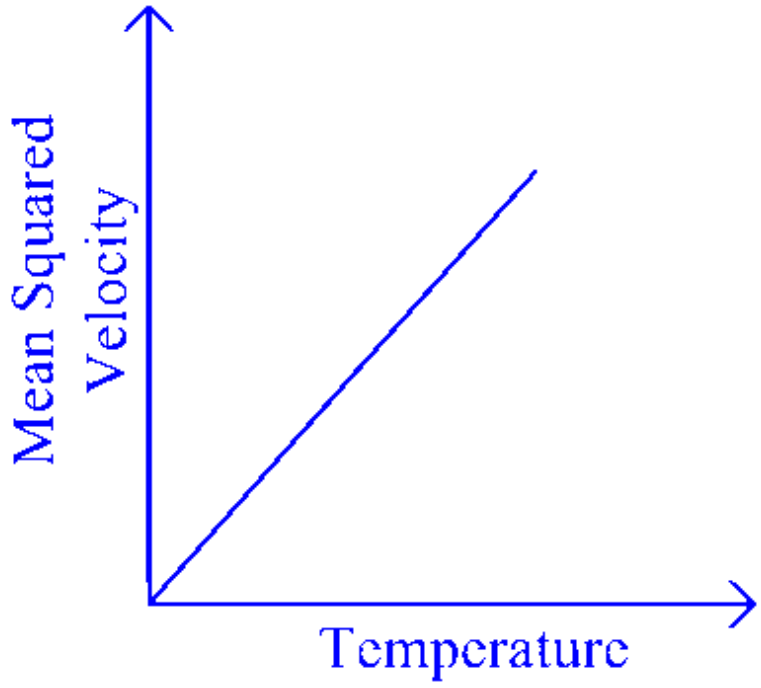
A.


Mean Squared
Velocity
Temperature

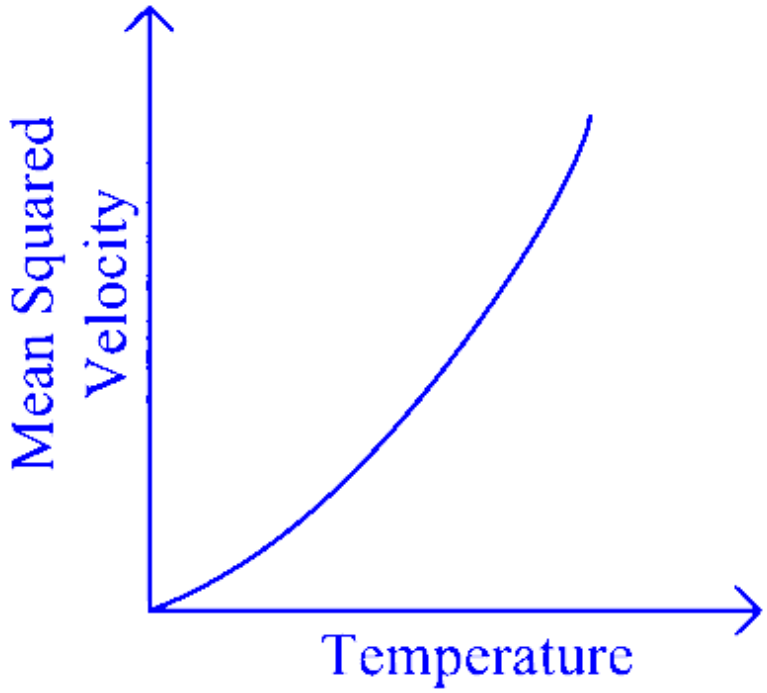
B.


Mean Squared
Velocity
Temperature

C.



D.



Answer: C

Solution:

We know, for an ideal gas,

$V_{rms} = \sqrt{\frac{3RT}{M}}$

$\Rightarrow V_{ms} = V_{rms}^2 = \frac{3RT}{M}$

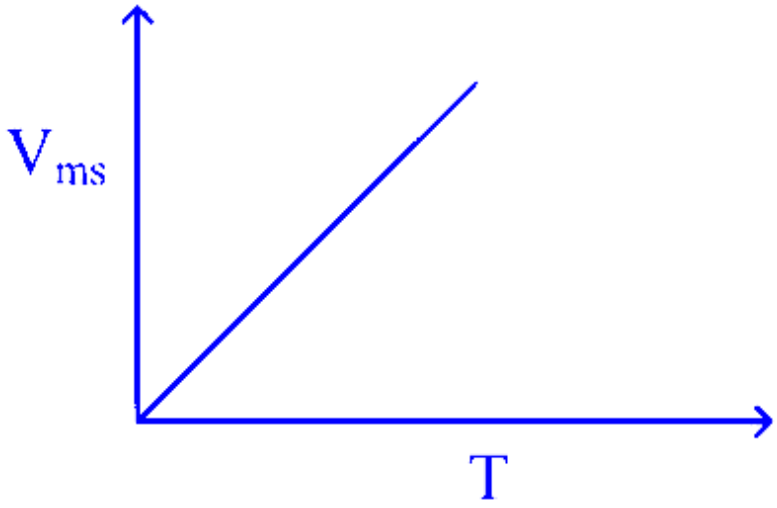
$\Rightarrow V_{ms} \propto T$

$\Rightarrow V_{ms} \propto T$

i.e. mean squared velocity is directly proportional to temperature.

$\Rightarrow V_{ms} = \left(\frac{3R}{M}\right)^{T}$

by comparing it with $y = mx$ (straight line)



Hence, option 3 is correct.

Question25

The kinetic energy of translation of the molecules in 50 g of CO_2 gas at 17°C is :

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Options:

A.

4205.5 J

B.

3582.7 J

C.

3986.3 J

D.

4102.8 J

Answer: D

Solution:

$$(\mathrm{KE})_{\text{Transsational}} = \left[\frac{3}{2}\mathrm{KT}\right] \times \text{ no. of molecule}$$

$$\text{No. of molecule } = \left[\frac{50}{44} \times 6.023 \times 10^{23}\right]$$

$$(\mathrm{KE})_{\text{Transsational}} = 4108.644 \text{ J}$$

Question26

The ratio of vapour densities of two gases at the same temperature is $\frac{4}{25}$, then the ratio of r.m.s. velocities will be :

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Options:

A.

$\frac{5}{2}$

B.

$\frac{25}{4}$

C.

$\frac{4}{25}$

D.

$\frac{2}{5}$

Answer: A

Solution:

We are given that the ratio of the vapour densities of the two gases is

$\frac{4}{25}$.

Since vapour density is proportional to the molecular mass, we can write

$\frac{M_1}{M_2} = \frac{4}{25}$,

where M_1 and M_2 are the molecular masses of the gases.

The root mean square (r.m.s.) velocity of a gas is given by

$v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$,

where:

R is the universal gas constant,

T is the temperature,

M is the molecular mass of the gas.

Since both gases are at the same temperature, the ratio of their r.m.s. velocities is

$\frac{v_{\text{rms},1}}{v_{\text{rms},2}} = \sqrt{\frac{M_2}{M_1}}$.

Substitute the ratio of molecular masses:

$\frac{v_{\text{rms},1}}{v_{\text{rms},2}} = \sqrt{\frac{25}{4}} = \frac{5}{2}$.

Thus, the ratio of their r.m.s. velocities is

$\frac{5}{2}$.

The correct answer is Option A: $\frac{5}{2}$.

Question27

The work done in an adiabatic change in an ideal gas depends upon only :

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Options:

A.

change in its pressure

B.

change in its temperature

C.

change in its specific heat

D.

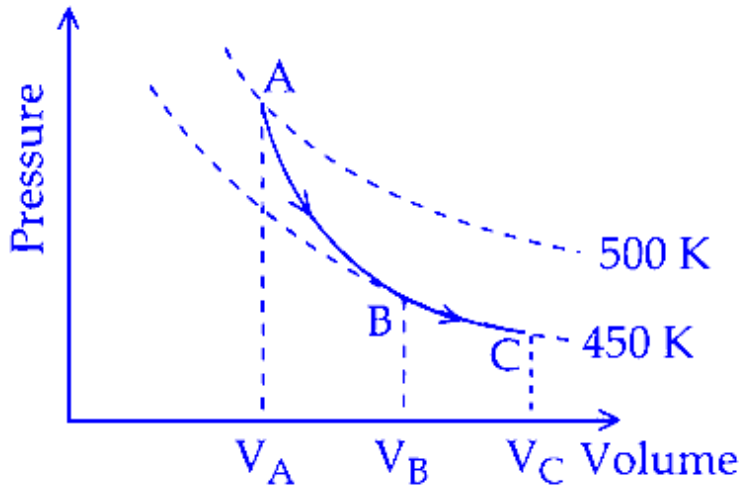
change in its volume

Answer: B

Solution:

$\Delta W = -\Delta U = -nC_v\Delta T$

Question28



A poly-atomic molecule ($C_V = 3R, C_P = 4R$, where R is gas constant) goes from phase space point
A $\left(P_A = 10^5\ Pa,\ V_A = 4 \times 10^{-6}\ m^3\right)$ to point
B $\left(P_B = 5 \times 10^4\ Pa,\ V_B = 6 \times 10^{-6}\ m^3\right)$ to point C $\left(P_C = 10^4\ Pa, V_C = 8 \times 10^{-6}\ m^3\right)$. A to B is an adiabatic path and B to C is an isothermal path.

The net heat absorbed per unit mole by the system is :

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Options:

A. $500\mathrm{R}(\ln 3+\ln 4)$

B. $450\mathrm{R}(\ln 4-\ln 3)$

C. $500\mathrm{R}\ln 2$

D. $400\mathrm{R}\ln 4$

Answer: B

Solution:

As A to B is can adiabatic path,

So, $\Delta Q_{A\to B}=o$ .... (1)

So, now we need to find the heat absorbed for the isothermal path (B to C)

We know, change in internal energy

$\Delta u=mc_v\Delta T$

$\Rightarrow \Delta u=o$ (for isothermal as $\Delta T=o$)

Now, using Ist law of thermodynamics

$\Delta Q=\Delta u+w$

$\Rightarrow \Delta Q=o+w\Rightarrow \Delta Q=w$

So, $\Delta Q_{B\to C}=W_{B\to C}$

$=nRT\ln\left(\frac{v_C}{v_B}\right)$

$\Rightarrow \Delta Q_{B\to C}=nR(450)\ln\left(\frac{4}{3}\right)$

$\Rightarrow \Delta Q_{B\to C}=450nR\ln\left(\frac{4}{3}\right)$ .... (2)

So net heat absorbed,

$Q=\Delta Q_{A\to B}+\Delta Q_{B\to C}$

$\Rightarrow Q=450nR\ln\left(\frac{4}{3}\right)$ ... (from 1 and 2)

Net heat absorbed per mole,

$\Rightarrow \frac{Q}{n}=450R(\ln 4-\ln 3)$.

Option 2 is correct.

Question29

A cup of coffee cools from 90°C to 80°C in t minutes when the room temperature is 20°C. The time taken by the similar cup of coffee to cool from 80°C to 60°C at the same room temperature is:

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Options:

A.

$\frac{13}{5}t$

B.

$\frac{10}{13}t$

C.

$\frac{5}{13}t$

D.

$\frac{13}{10}t$

Answer: A

Solution:

Here, we will use the Newton's law of cooling.

We know, $\frac{T_1-T_2}{\Delta t} = k\left(\frac{T_1+T_2}{2} - T_s\right)$ .... (1)

where, T_1 and T_2 are initial and final temperatures respectively.

T_s = surrounding temperature

Δt = time taken

k = positive constant

Given,

Ist case :

$T_1 = 90^\circ C$

$T_2 = 80^\circ C$

$\Delta t = t, T_s = 20^\circ C$

IInd case :

$T_1 = 80^\circ C$

$T_2 = 60^\circ C$

$T_s = 20^\circ C, \Delta t = ?$

Now, for Ist case,

$\frac{90-80}{t} = k\left(\frac{90+80}{2} - 20\right)$ ..... (from (1))

$\Rightarrow \frac{10}{t} = k\left(85 - 20\right)$

$\Rightarrow \frac{10}{t} = 65k$ .... (2)

For IInd case,

$\frac{80-60}{\Delta t} = k\left(\frac{80+60}{2} - 20\right)$ .... (From (1))

$\Rightarrow \frac{20}{\Delta t} = k\left(70 - 20\right)$

$\Rightarrow \frac{20}{\Delta t} = 50k$ .... (3)

Now, by (2) $\div$ (3),

$\frac{\frac{10}{t}}{\frac{20}{\Delta t}} = \frac{13}{10}$

$\Rightarrow \frac{\Delta t}{t}\left(\frac{1}{2}\right) = \frac{13}{5}$

$\Rightarrow \Delta t = \frac{13}{5}t$

Question30

Given below are two statements. One is labelled as Assertion (A) and the other is labelled as Reason (R).

Assertion (A) : With the increase in the pressure of an ideal gas, the volume falls off more rapidly in an isothermal process in comparison to the adiabatic process.

Reason (R) : In isothermal process, PV = constant, while in adiabatic process PV^γ = constant. Here γ is the ratio of specific heats, P is the pressure and V is the volume of the ideal gas.

In the light of the above statements, choose the correct answer from the options given below:

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Options:

A.

(A) is true but (R) is false

B.

Both (A) and (R) are true but (R) is NOT the correct explanation of (A)

C.

(A) is false but (R) is true

D.

Both (A) and (R) is the correct explanation of (A)

Answer: D

Solution:

We know, ideal gas equation,

$Pv = nRT$

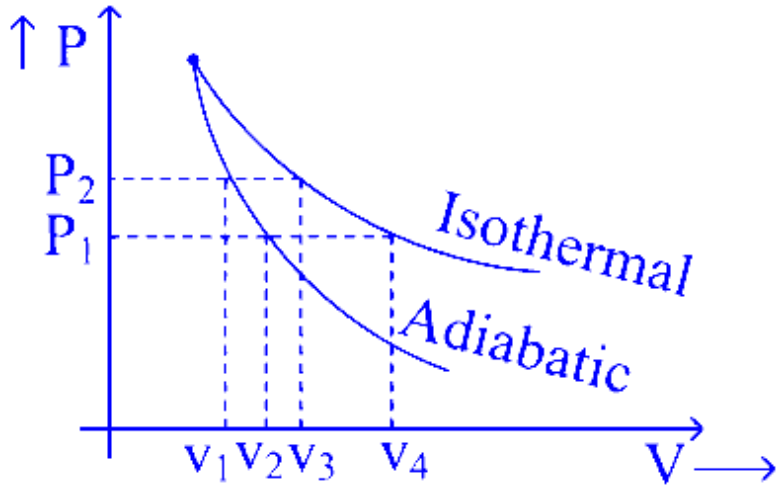
For isothermal process, T = constant

$\Rightarrow PV = \text{const.}$

$\Rightarrow P \propto \frac{1}{V}$

For an adiabatic process,

$PV^r = \text{constant}$



We can see, for the same pressure incresement, $P_2 - P_1$, $(v_4 - v_3) > (v_2 - v_1)$

i.e. the volume falls off more rapidly in an isothermal process in comparison to the adiabatic process. Hence, option 4 is corret.

Question31

The difference of temperature in a material can convert heat energy into electrical energy. To harvest the heat energy, the material should have

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Options:

A.

low thermal conductivity and high electrical conductivity

B.

low thermal conductivity and low electrical conductivity

C.

high thermal conductivity and high electrical conductivity

D.

high thermal conductivity and low electrical conductivity

Answer: A

Solution:

To convert a temperature difference into electrical energy effectively, the material in question should have low thermal conductivity and high electrical conductivity. Such materials are classified as thermoelectric materials.

A low thermal conductivity ensures that the material does not easily transfer heat, which is crucial for maintaining a significant temperature difference between its hot and cold sides. This helps in generating a greater voltage. Meanwhile, high electrical conductivity is essential for facilitating the efficient movement of electrons across the material when there is a temperature difference, leading to maximal energy conversion.

Therefore, a material that optimally harvests heat energy into electrical energy should embody these characteristics.

Question32

The equation for real gas is given by $\left(\mathrm{P}+\frac{\mathrm{a}}{\mathrm{V}^2}\right)(\mathrm{V}-\mathrm{b})=\mathrm{RT}$, where $\mathrm{P}, \mathrm{V}, \mathrm{T}$ and R are the pressure, volume, temperature and gas constant, respectively. The dimension of ab^{-2} is equivalent to that of :

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Options:

A. Compressibility

B. Planck's constant

C. Energy density

D. Strain

Answer: C

Solution:

The equation for a real gas is given by:

$\left(\mathrm{P}+\frac{\mathrm{a}}{\mathrm{V}^2}\right)(\mathrm{V}-\mathrm{b})=\mathrm{RT}$

Here, P, V, T, and R are the pressure, volume, temperature, and gas constant, respectively.

To find the dimension of ab^{-2}, we proceed with the following steps:

Rearrange the equation for dimensions:

$[a] = [P][V^2]$

Since $[P] = ML^{-1}T^{-2}$ and $[V] = L^3$, we have:

$[a] = ML^{-1}T^{-2}(L^6) = ML^5T^{-2}$

As derived from the equation:

$[b] = [V] = L^3$

Now, to find $[ab^{-2}]$:

$[ab^{-2}] = \frac{[a]}{[b]^2} = ML^5T^{-2} \cdot L^{-6} = ML^{-1}T^{-2}$

This dimension, $ML^{-1}T^{-2}$, is equivalent to the dimension of energy density.

Question33

In an adiabatic process, which of the following statements is true?

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Options:

A. The internal energy of the gas decreases as the temperature increases

B. The molar heat capacity is zero

C. Work done by the gas equals the increase in internal energy

D. The molar heat capacity is infinite

Answer: B

Solution:

Option B is correct.

• In an adiabatic process no heat is exchanged, so

$\delta Q = 0$.

• The (molar) heat capacity for any process is defined by

$C = \frac{\delta Q}{n\, dT}$.

Since $\delta Q = 0$ even when $dT \neq 0$, it follows that

$C_{\text{adiabatic}} = 0$.

All other statements are therefore false.

Question34

Identify the characteristics of an adiabatic process in a monoatomic gas.(A) Internal energy is constant.(B) Work done in the process is equal to the change in internal energy.(C) The product of temperature and volume is a constant.(D) The product of pressure and volume is a constant.(E) The work done to change the temperature from T_1 to T_2 is proportional to $\left(\mathrm{T}_2-\mathrm{T}_1\right)$.Choose the correct answer from the options given below :

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Options:

A. (B), (D) only

B. (B), (E) only

C. (A), (C), (E) only

D. (A), (C), (D) only

Answer: B

Solution:

In an adiabatic process, the key characteristics for a monoatomic gas are:

No Heat Exchange: The adiabatic process occurs without heat transfer, meaning $Q = 0$.

Work Done and Internal Energy Change: The work done on or by the system is equal to the change in internal energy. Mathematically, this is expressed as:

$\Delta U = -W$

where ΔU is the change in internal energy and W is the work done.

Work and Temperature Relationship: The work done when changing the temperature from T_1 to T_2 is proportional to the difference between these temperatures. This relationship can be expressed as:

$|\text{Work Done}| = nC_v\Delta T \propto (T_2 - T_1)$

Here, n is the number of moles, C_v is the molar heat capacity at constant volume, and ΔT is the change in temperature.

From these characteristics, the correct features of an adiabatic process in a monoatomic gas relate to the relationships involving work done and temperature change, specifically options (B) and (E).

Question35

Match List - I with List - II

	List - I	$List - II$
(A)	Heat capacity of body	(I) $\mathrm{J\,kg^{-1}}$
(B)	Specific heat capacity of body	(II) $\mathrm{J\,K^{-1}}$
(C)	Latent heat	(III) $\mathrm{J\,kg^{-1}\,K^{-1}}$
(D)	Thermal conductivity	(IV) $\mathrm{J\,m^{-1}\,K^{-1}\,s^{-1}}$

Choose the correct answer from the options given below :

Options:

A. (A)-(IV), (B)-(III), (C)-(II), (D)-(I)

B. (A)-(III), (B)-(I), (C)-(II), (D)-(IV)

C. (A)-(III), (B)-(IV), (C)-(I), (D)-(II)

D. (A)-(II), (B)-(III), (C)-(I), (D)-(IV)

Answer: D

Solution:

To match the entries in List-I with their corresponding units in List-II, we can use the definitions and formulas related to each concept in thermal physics:

Heat Capacity of a Body (C') is defined as:

$C' = \frac{\Delta Q}{\Delta T}$

The unit for heat capacity (C') is Joules per Kelvin ($\mathrm{J\,K^{-1}}$).

Specific Heat Capacity of a Body (S) indicates how much heat energy is required to change the temperature of a unit mass of a substance by one degree Kelvin:

$S = \frac{\Delta Q}{m\Delta T}$

The unit for specific heat capacity (S) is Joules per kilogram per Kelvin (J kg^{-1} K^{-1}).

Latent Heat (L) is the heat energy absorbed or released during a phase change of a substance at a constant temperature:

$L = \frac{\Delta Q}{m}$

The unit for latent heat (L) is Joules per kilogram (J kg^{-1}).

Thermal Conductivity (K) measures the ability of a material to conduct heat:

$\Delta Q = \frac{KA\Delta T}{L} \quad \Rightarrow \quad K = \frac{\Delta Q \cdot L}{A\Delta T}$

The unit for thermal conductivity (K) is Joules per meter per Kelvin per second (J m^{-1} K^{-1} s^{-1}).

Using these formulas and their corresponding units, the correct matches are:

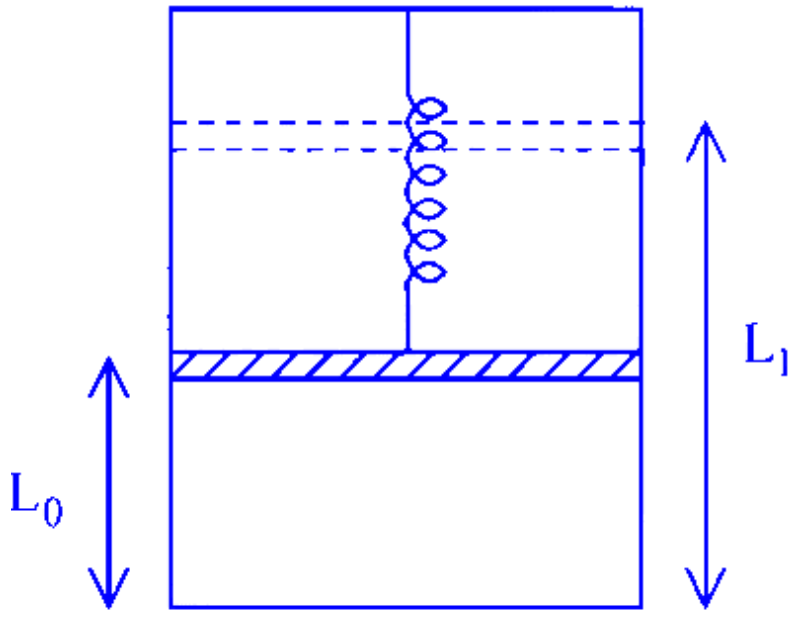
(A) Heat capacity of body $\rightarrow$ (II) J K^{-1}

(B) Specific heat capacity of body $\rightarrow$ (III) J kg^{-1} K^{-1}

(C) Latent heat $\rightarrow$ (I) J kg^{-1}

(D) Thermal conductivity $\rightarrow$ (IV) J m^{-1} K^{-1} s^{-1}

Question36



A piston of mass M is hung from a massless spring whose restoring force law goes as $F = -kx^3$, where k is the spring constant of appropriate dimension. The piston separates the vertical chamber into two parts, where the bottom part is filled with ' n ' moles of an ideal gas. An external work is done on the gas isothermally (at a constant temperature T) with the help of a heating filament (with

negligible volume) mounted in lower part of the chamber, so that the piston goes up from a height L_0 to L_1, the total energy delivered by the filament is:(Assume spring to be in its natural length before heating)

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Options:

A. $nRT \ln\left(\frac{L_1}{L_0}\right) + Mg\left(L_1 - L_0\right) + \frac{3k}{4}\left({L_1}^4 - {L_0}^4\right)$

B. $nRT \ln\left(\frac{L_1}{L_0}\right) + Mg\left(L_1 - L_0\right) + \frac{k}{4}\left(L_1^4 - {L_0}^4\right)$

C. $nRT \ln\left(\frac{L_1^2}{L_0^2}\right) + \frac{Mg}{2}\left(L_1 - L_0\right) + \frac{k}{4}\left(L_1^4 - {L_0}^4\right)$

D. $3nRT \ln\left(\frac{L_1}{L_0}\right) + 2Mg\left(L_1 - L_0\right) + \frac{k}{3}\left({L_1}^3 - {L_0}^3\right)$

Answer: B

Solution:

Using WET

Total energy supplied = gravitational potential energy + spring potential energy + work done by gas

$$\mathrm{Mg\left(L_1 - L_0\right) + \int_{L_0}^{L_1} kx^3 dx + nRT\ell n}$$

$$\left[\frac{\mathrm{L_1\ A}}{\mathrm{L_0\ A}}\right] + \mathrm{W_{ext}} = 0$$

$$\frac{\mathrm{K}}{4}\left[\mathrm{x^4}\right]_{\mathrm{L_0}}^{\mathrm{L_1}} + \mathrm{Mg\left(L_1 - L_0\right) + \int_{L_0}^{L_1} kx^3 dx + nRT\ell n}$$

$$\left[\frac{\mathrm{L_1}}{\mathrm{L_0}}\right] + \mathrm{W_{ext}} = 0$$

$$\frac{\mathrm{k}}{4}\left(\mathrm{L_1^4 - L_0^4}\right) + \mathrm{Mg\left(L_1 - L_0\right) + nRT\ell n}$$

$$\left[\frac{\mathrm{L_1}}{\mathrm{L_0}}\right] + \mathrm{W_{ext}} = 0$$

$$\mathrm{W_{ext}} = \frac{\mathrm{k}}{4}\left(\mathrm{L_1^4 - L_0^4}\right) + \mathrm{Mg\left(L_1 - L_0\right) + nRT\ell n}\left[\frac{\mathrm{L_1}}{\mathrm{L_0}}\right]$$

Question37

During the melting of a slab of ice at 273 K at atmospheric pressure :

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Options:

A. Internal energy of ice-water system remains unchanged.

B. Positive work is done by the ice-water system on the atmosphere.

C. Positive work is done on the ice-water system by the atmosphere.

D. Internal energy of the ice-water system decreases.

Answer: C

Solution:

During the melting of a slab of ice at 273 K under atmospheric pressure, the following occurs:

As the ice melts, its volume decreases. Because of this volume reduction, the atmosphere exerts a positive work on the ice-water system. When heat is absorbed by the ice-water system, we denote the absorbed heat as ΔQ, which is positive. The work done by the ice-water system is negative because it is being compressed by the external pressure.

According to the first law of thermodynamics:

$$\Delta U = \Delta Q + \Delta W$$

In this equation, ΔU represents the change in internal energy, ΔQ is the heat absorbed by the system, and ΔW is the work done by the system. Since the work done is negative and the absorbed heat is positive, the overall internal energy (ΔU) increases.

Question38

A gas is kept in a container having walls which are thermally non-conducting. Initially the gas has a volume of $800\ \mathrm{cm}^3$ and temperature $27^\circ\mathrm{C}$. The change in temperature when the gas is adiabatically compressed to $200\ \mathrm{cm}^3$ is:

(Take $\gamma = 1.5$; γ is the ratio of specific heats at constant pressure and at constant volume)

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Options:

A. 300 K

B. 600 K

C. 327 K

D. 522 K

Answer: A

Solution:

To determine the change in temperature when a gas is adiabatically compressed, we are given the following initial conditions:

Initial volume, $V_1 = 800\,\text{cm}^3$

Final volume, $V_2 = 200\,\text{cm}^3$

Initial temperature, $T_1 = 27^\circ\text{C} = 300\,\text{K}$

Adiabatic index (ratio of specific heats) $\gamma = 1.5$

In an adiabatic process, the relationship between temperature and volume is given by the equation:

$TV^{\gamma-1} = \text{constant}$

Applying this to the initial and final states:

$300 \times (800)^{0.5} = T_2 \times (200)^{0.5}$

Solving for the final temperature T_2:

$T_2 = 300 \times \left(\frac{800}{200}\right)^{0.5} = 300 \times (4)^{0.5}$

$T_2 = 300 \times 2 = 600\,\text{K}$

Thus, the change in temperature is:

$\Delta T = T_2 - T_1 = 600\,\text{K} - 300\,\text{K} = 300\,\text{K}$

Therefore, when the gas is adiabatically compressed, the temperature increases by 300 K.

Question39

Pressure of an ideal gas, contained in a closed vessel, is increased by 0.4% when heated by $1^{\circ}\mathrm{C}$. Its initial temperature must be:

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Options:

A. 2500 K

B. $25^{\circ}\mathrm{C}$

C. $250^{\circ}\mathrm{C}$

D. 250 K

Answer: D

Solution:

In this scenario, we're dealing with an isochoric process, meaning the volume of the gas remains constant. For an ideal gas in an isochoric process, the pressure (P) is directly proportional to the temperature (T) in Kelvin.

The relationship can be expressed as:

$P \propto T$

Given the percentage increase in pressure is 0.4% when the temperature is increased by $1^{\circ}\mathrm{C}$, we can use the relationship:

$\frac{\Delta P}{P} = \frac{\Delta T}{T}$

Substituting the given values into the equation, we have:

$\frac{0.4}{100} = \frac{1}{T}$

Solving for T, we find:

$T = 250\,\mathrm{K}$

Therefore, the initial temperature of the gas in the vessel must be $250\,\mathrm{K}$.

Question40

An ideal gas exists in a state with pressure P_0, volume V_0. It is isothermally expanded to 4 times of its initial volume (V_0), then isobarically compressed to its original volume. Finally the system is heated isochorically to bring it to its initial state. The amount of heat exchanged in this process is

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Options:

A. $P_0\ V_0(\ln 2 - 0.75)$

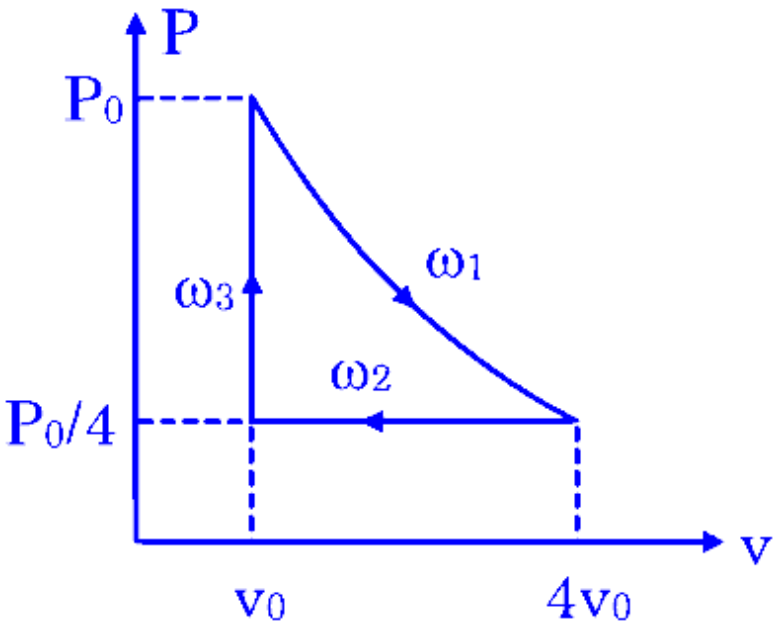
B. $P_0\ V_0(2\ln 2 - 0.75)$

C. $P_0\ V_0(2\ln 2 - 0.25)$

D. $P_0\ V_0(\ln 2 - 0.25)$

Answer: B

Solution:



$\omega_1 = P_0 v_0 \ell n 4$

$\omega_2 = \frac{P_0}{4}(-3v_0) = -\frac{3P_0 v_0}{4}$

$\omega_3 = 0$

$Q_T = \Delta U_{cyclic} + \omega$

$Q_T = \omega \quad (\Delta U_{cyclic} = 0)$

$Q_T = P_0 v_0 \left(\ln 4 - \frac{3}{4}\right)$

$= P_0 v_0 (2\ln 2 - 0.75)$

Question41

The mean free path and the average speed of oxygen molecules at 300 K and 1 atm are $3 \times 10^{-7}\ \mathrm{m}$ and $600\ \mathrm{m/s}$, respectively. Find the frequency of its collisions.

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Options:

A. $5 \times 10^{8}/\mathrm{s}$

B. $9 \times 10^{5}/\mathrm{s}$

C. $2 \times 10^{10}/\mathrm{s}$

D. $2 \times 10^{9}/\mathrm{s}$

Answer: D

Solution:

To determine the frequency of collisions for oxygen molecules, we use the formula for frequency:

Frequency $= \frac{1}{T} = \frac{V_{\text{avg}}}{\lambda}$

where V_{avg} is the average speed of the molecules and λ is the mean free path.

Given:

Average speed (V_{avg}) = 600 m/s

Mean free path (λ) = 3×10^{-7} m

Substitute these values into the formula:

Frequency $= \frac{600}{3 \times 10^{-7}} = 2 \times 10^{9}\ \mathrm{s}^{-1}$

Therefore, the frequency of collisions is 2×10^{9} collisions per second.

Question42

Consider the sound wave travelling in ideal gases of $\mathrm{He}, \mathrm{CH_4}$, and $\mathrm{CO_2}$. All the gases have the same ratio $\frac{P}{\rho}$, where P is the pressure

and ρ is the density. The ratio of the speed of sound through the gases $V_{He} : V_{CH_4} : V_{CO_2}$ is given by

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Options:

A. $\sqrt{\frac{7}{5}} : \sqrt{\frac{5}{3}} : \sqrt{\frac{4}{3}}$

B. $\sqrt{\frac{5}{3}} : \sqrt{\frac{4}{3}} : \sqrt{\frac{4}{3}}$

C. $\sqrt{\frac{5}{3}} : \sqrt{\frac{4}{3}} : \sqrt{\frac{7}{5}}$

D. $\sqrt{\frac{4}{3}} : \sqrt{\frac{5}{3}} : \sqrt{\frac{7}{5}}$

Answer: C

Solution:

The speed of sound in an ideal gas is given by

$v = \sqrt{\gamma \frac{P}{\rho}},$

where:

γ is the ratio of specific heats,

P is the pressure, and

ρ is the density.

Since the problem states that $\frac{P}{\rho}$ is the same for all the gases, the speed of sound in each gas is determined solely by the factor $\sqrt{\gamma}$.

Let's determine the appropriate γ for each gas:

Helium (He):

Helium is a monatomic gas.

For a monatomic gas, $\gamma = \frac{5}{3}$.

Therefore, $v_{He} \propto \sqrt{\frac{5}{3}}$.

Methane (CH_4):

Methane is a polyatomic gas (a tetrahedral molecule with three rotational degrees of freedom).

For nonlinear polyatomic gases, γ is typically taken as $\frac{4}{3}$.

Thus, $v_{CH_4} \propto \sqrt{\frac{4}{3}}$.

Carbon Dioxide (CO_2):

Carbon dioxide is a linear molecule.

For linear molecules, $\gamma = \frac{7}{5}$.

Hence, $v_{CO_2} \propto \sqrt{\frac{7}{5}}$.

Therefore, the ratio of the speeds of sound in the gases is:

$v_{He} : v_{CH_4} : v_{CO_2} = \sqrt{\frac{5}{3}} : \sqrt{\frac{4}{3}} : \sqrt{\frac{7}{5}}$.

Comparing this expression with the given options, we see that it matches **Option C**.

Question43

Match List - I with List - II.

	List - I		List - II
(A)	Isobaric	(I)	$\Delta Q = \Delta W$
(B)	Isochoric	(II)	$\Delta Q = \Delta U$
(C)	Adiabatic	(III)	$\Delta Q =$ zero
(D)	Isothermal	(IV)	$\Delta Q = \Delta U + P\Delta V$

$\Delta Q =$ Heat supplied

$\Delta W =$ Work done by the system

$\Delta \mathrm{U} =$ Change in internal energy

$\mathrm{P} =$ Pressure of the system

$\Delta \mathrm{V} =$ Change in volume of the system

Choose the correct answer from the options given below :

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Options:

A. (A)-(IV), (B)-(I), (C)-(III), (D)-(II)

B. (A)-(IV), (B)-(II), (C)-(III), (D)-(I)

C. (A)-(IV), (B)-(III), (C)-(II), (D)-(I)

D. (A)-(II), (B)-(IV), (C)-(III), (D)-(I)

Answer: B

Solution:

(A) Isobaric $(\mathrm{P}=\mathrm{C})$

$\Delta \mathrm{Q}=\Delta \mathrm{U}+\mathrm{P} \Delta \mathrm{V}$

(B) Isochoric $(\mathrm{V}=\mathrm{C})$

$\Delta \mathrm{Q}=\Delta \mathrm{U}$

(C) Adiabatic $(\Delta \mathrm{Q}=0)$

$\Delta \mathrm{Q}=0$

(D) Isothermal $(\Delta \mathrm{U}=0)$

$\Delta \mathrm{Q}=\Delta \mathrm{W}$

Question44

There are two vessels filled with an ideal gas where volume of one is double the volume of other. The large vessel contains the gas at 8 kPa at 1000 K while the smaller vessel contains the gas at 7 kPa at 500 K . If the vessels are connected to each other by a thin tube allowing the gas to flow and the temperature of both vessels is maintained at 600 K , at steady state the pressure in the vessels will be (in kPa).

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Options:

A. 24

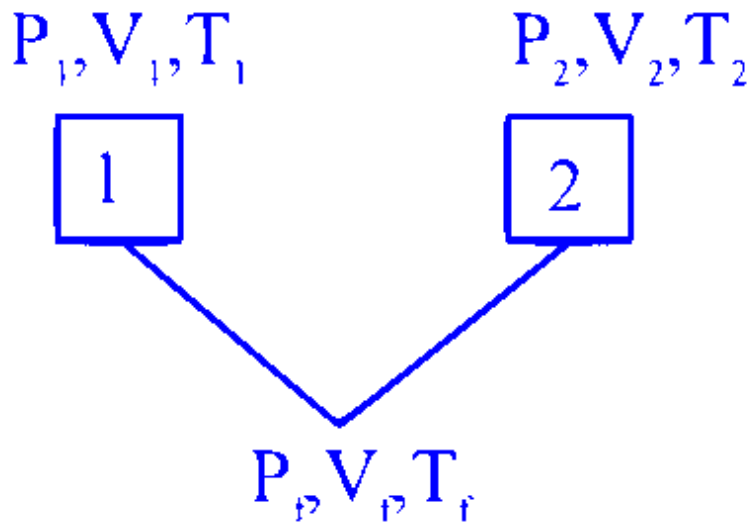
B. 4.4

C. 18

D. 6

Answer: D

Solution:



Number of masses will remain constant

$$n_1 + n_2 = n_f$$

$$\frac{P_1\,V_1}{RT_1} + \frac{P_2\,V_2}{RT_2} = \frac{P_f\,V_f}{RT_f}$$

$$\frac{8 \times 2\,V}{R \times 1000} + \frac{7 \times V}{R \times 500} = \frac{P_f(3\,V)}{R \times 600}$$

$$\frac{16}{1000} + \frac{14}{1000} = \frac{P_f}{R \times 600}$$

$$\frac{30}{1000} = \frac{P_f}{200}$$

$$P_f = 6\text{kPa}$$

Question45

Consider a rectangular sheet of solid material of length $l = 9$ cm and width $\mathrm{d} = 4$ cm. The coefficient of linear expansion is $\alpha = 3.1 \times 10^{-5}\ \mathrm{K}^{-1}$ at room temperature and one atmospheric pressure. The mass of sheet $m = 0.1$ kg and the specific heat capacity

$C_{\mathrm{v}} = 900\ \mathrm{J\ kg^{-1}\ K^{-1}}$. If the amount of heat supplied to the material is $8.1 \times 10^2\ \mathrm{J}$ then change in area of the rectangular sheet is :

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Options:

A. $2.0 \times 10^{-6}\ \mathrm{m^2}$

B. $6.0 \times 10^{-7}\ \mathrm{m^2}$

C. $3.0 \times 10^{-7}\ \mathrm{m^2}$

D. $4.0 \times 10^{-7}\ \mathrm{m^2}$

Answer: A

Solution:

Calculate the Change in Temperature:

Use the formula:

$\Delta Q = mC_v\Delta T$

Given:

$\Delta Q = 8.1 \times 10^2\,\mathrm{J}$

$m = 0.1\,\mathrm{kg}$

$C_v = 900\,\mathrm{J\,kg^{-1}\,K^{-1}}$

Substitute the values to find ΔT:

$8.1 \times 10^2 = 0.1 \times 900 \times \Delta T$

Solving for ΔT:

$\Delta T = \frac{8.1\times10^2}{0.1\times900} = 9\,\mathrm{K}$

Calculate the Change in Area:

The change in area ΔA is calculated using:

$\Delta A = A_0 \times 2\alpha\Delta T$

Where:

A_0 is the original area of the sheet.

$\alpha = 3.1 \times 10^{-5}\,\mathrm{K}^{-1}$.

$\Delta T = 9\,\mathrm{K}$.

First, calculate the original area A_0:

$A_0 = l \times d = 9\,\mathrm{cm} \times 4\,\mathrm{cm} = 36\,\mathrm{cm}^2 = 0.0036\,\mathrm{m}^2$

Now, substitute into the formula for ΔA:

$\Delta A = 0.0036 \times 2 \times 3.1 \times 10^{-5} \times 9$

Simplifying:

$\Delta A = 2.0 \times 10^{-6}\,\mathrm{m}^2$

Therefore, the change in area of the rectangular sheet is $\boxed{2.0 \times 10^{-6}\,\mathrm{m}^2}$.

Question46

Match the List I with List II

	List - I		List - II
(A)	Triatomic rigid gas	(I)	$\frac{C_p}{C_v} = \frac{5}{3}$
(B)	Diatomic non-rigid gas	(II)	$\frac{C_p}{C_v} = \frac{7}{5}$
(C)	Monoatomic gas	(III)	$\frac{C_p}{C_v} = \frac{4}{3}$
(D)	Diatomic rigid gas	(IV)	$\frac{C_p}{C_v} = \frac{9}{7}$

Choose the correct answer from the options given below:

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Options:

A. A-III, B-IV, C-I, D-II

B. A-II, B-IV, C-I, D-III

C. A-IV, B-II, C-III, D-I

D. A-III, B-II, C-IV, D-I

Answer: A

Solution:

The explanation uses the equation for the heat capacity ratio, $\gamma = 1 + \frac{2}{f}$, where f is the degrees of freedom of the gas. Here's how it applies to different types of gases:

Triatomic Rigid Gas:

Degrees of freedom (f) = 6

$\gamma = 1 + \frac{2}{6} = \frac{4}{3}$

Diatomic Non-Rigid Gas:

Degrees of freedom (f) = 7

$\gamma = 1 + \frac{2}{7} = \frac{9}{7}$

Diatomic Rigid Gas:

Degrees of freedom (f) = 5

$\gamma = 1 + \frac{2}{5} = \frac{7}{5}$

Monoatomic Gas:

Degrees of freedom (f) = 3

$\gamma = 1 + \frac{2}{3} = \frac{5}{3}$

Therefore, when matching List I with List II, the correct pairing is:

A (Triatomic rigid gas) - **III** $(\frac{4}{3})$

B (Diatomic non-rigid gas) - **IV** $(\frac{9}{7})$

C (Monoatomic gas) - **I** $(\frac{5}{3})$

D (Diatomic rigid gas) - **II** $(\frac{7}{5})$

Thus, the correct answer from the options given is:

A-III, B-IV, C-I, D-II

Question47

Match List - I with List - II.

List - I	List - II

(A) Isothermal	(I) ΔW (work done) = 0
(B) Adiabatic	(II) ΔQ (supplied heat) = 0
(C) Isobaric	(III) ΔU (change in internal energy) $\neq 0$
(D) Isochoric	(IV) $\Delta U = 0$

Choose the correct answer from the options given below :

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Options:

A.

(A)-(III), (B)-(II), (C)-(I), (D)-(IV)

B.

(A)-(II), (B)-(IV), (C)-(I), (D)-(III)

C.

(A)-(IV), (B)-(II), (C)-(III), (D)-(I)

D.

(A)-(IV), (B)-(I), (C)-(III), (D)-(II)

Answer: C

Solution:

To accurately match the terms from List-I with the corresponding statements in List-II, consider the properties of each thermodynamic process:

Isothermal Process (A):

During an isothermal process, the temperature remains constant ($\Delta T = 0$), which means that the change in internal energy (ΔU) is zero. Therefore, it corresponds to (IV).

Adiabatic Process (B):

In an adiabatic process, no heat is exchanged with the surroundings ($\Delta Q = 0$). This matches with (II).

Isobaric Process (C):

An isobaric process involves constant pressure conditions ($\Delta P = 0$), but internal energy (ΔU) can change. Thus, it's associated with (III).

Isochoric Process (D):

For an isochoric process, volume remains constant ($\Delta V = 0$), which means that no work is done ($\Delta W = 0$). This aligns with (I).

Based on these descriptions, the correct matching is:

(A) Isothermal → (IV)

(B) Adiabatic → (II)

(C) Isobaric → (III)

(D) Isochoric → (I)

Question48

The helium and argon are put in the flask at the same room temperature (300 K). The ratio of average kinetic energies (per molecule) of helium and argon is:

(Give: Molar mass of helium = 4 g/mol, Molar mass of argon = 40 g/mol)

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Options:

A.

$1 : \sqrt{10}$

B.

$10 : 1$

C.

$1 : 10$

D.

$1 : 1$

Answer: D

Solution:

Given the same room temperature of 300 K for helium and argon, we are tasked with finding the ratio of their average kinetic energies per molecule.

Formula for Kinetic Energy per Molecule:

$\mathrm{K.E.} = \frac{\mathrm{f}}{2}\mathrm{kT}$

In this equation:

f is the degrees of freedom, which is 3 for both helium (He) and argon (Ar) since they are monatomic gases.

k is the Boltzmann constant.

T is the temperature in Kelvin.

Kinetic Energy Comparison:

For both helium and argon, since $\mathrm{f} = 3$, the expression simplifies:

$\frac{\mathrm{K{\cdot}E_{He}}}{\mathrm{K{\cdot}E_{Ar}}} = \frac{1}{1}$

Thus, the average kinetic energy per molecule for both gases is the same at the same temperature, leading to a ratio of:

1 : 1

This result implies that despite their differences in molar masses (helium being 4 g/mol and argon 40 g/mol), the average kinetic energy per molecule remains equal at the same temperature.

Question49

Water falls from a height of 200 m into a pool. Calculate the rise in temperature of the water assuming no heat dissipation from the water in the pool.

(Take g = 10 m/s^2, specific heat of water = 4200 J/(kg K))

JEE Main 2025 (Online) 8th April Evening Shift

Options:

A.

0.36 K

B.

0.23 K

C.

0.48 K

D.

0.14 K

Answer: C

Solution:

To find the rise in temperature of the water as it falls from a height, we start by equating the potential energy loss to the heat gained, assuming no heat is lost from the water in the pool.

The potential energy lost by the water can be expressed as:

mgh

where:

m is the mass of water,

g is the acceleration due to gravity (10 m/s²),

h is the height (200 m).

The heat gained by the water when temperature changes is given by:

$ms\Delta T$

where:

s is the specific heat capacity of water (4200 J/(kg K)),

ΔT is the change in temperature.

Setting the potential energy loss equal to the heat gained:

$mgh = ms\Delta T$

We can simplify this equation by canceling out the mass m:

$gh = s\Delta T$

Now, solve for ΔT:

$\Delta T = \frac{gh}{s}$

Substitute the known values:

$\Delta T = \frac{10 \times 200}{4200}$

Calculate ΔT:

$\Delta T = \frac{2000}{4200}$

Simplify the fraction:

$\Delta T = \frac{10}{21}$

Therefore, the rise in temperature is $\Delta T \approx 0.48\,\text{K}$.

Question50

A monoatomic gas having $\gamma = \frac{5}{3}$ is stored in a thermally insulated container and the gas is suddenly compressed to $\left(\frac{1}{8}\right)^{\text{th}}$ of its initial volume. The ratio of final pressure and initial pressure is:

(γ is the ratio of specific heats of the gas at constant pressure and at constant volume)

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Options:

A.

16

B.

32

C.

28

D.

40

Answer: B

Solution:

To find the ratio of final pressure (P_f) to initial pressure (P_i), we use the adiabatic condition:

$P_i V_i^{\gamma} = P_f V_f^{\gamma}$

We aim to express the pressure ratio:

$\frac{P_f}{P_i} = \left(\frac{V_i}{V_f}\right)^{\gamma}$

Given that the final volume V_f is $\frac{1}{8}$ of the initial volume V_i, this simplifies to:

$\left(\frac{V_i}{V_f}\right) = 8$

Thus, the pressure ratio becomes:

$\frac{P_f}{P_i} = 8^{\frac{5}{3}}$

Calculating $8^{\frac{5}{3}}$ gives:

$\frac{P_f}{P_i} = 32$

Question51

0.08kg air is heated at constant volume through 5°C. The specific heat of air at constant volume is 0.17kcal⁄kg°C and J = 4.18 joule⁄cal. The change in its internal energy is approximately.

[27-Jan-2024 Shift 1]

Options:

A.

318J

B.

298J

C.

284J

D.

142J

Answer: C

Solution:

$Q = \Delta U$ as work done is zero [constant volume]

$\Delta U = ms\,\Delta T$

$= 0.08 \times (170 \times 4.18) \times 5$

$\simeq 284J$

Question52

During an adiabatic process, the pressure of a gas is found to be proportional to the cube of its absolute temperature. The ratio of C_p/C_v for the gas is :

[27-Jan-2024 Shift 2]

Options:

A.

5/3

B.

3/2

C.

7/5

D.

9/7

Answer: B

Solution:

$P \propto T^3 \Rightarrow PT^{-3} = \text{constant}$

$PV^{\gamma} = \text{const}$

$P\left(\frac{nRT}{P}\right)^{\gamma} = \text{const}$

$P^{1-\gamma}T^{\gamma} = \text{const}$

$PT^{\frac{\gamma}{1-\gamma}} = \text{const}$

$\frac{\gamma}{1-\gamma} = -3$

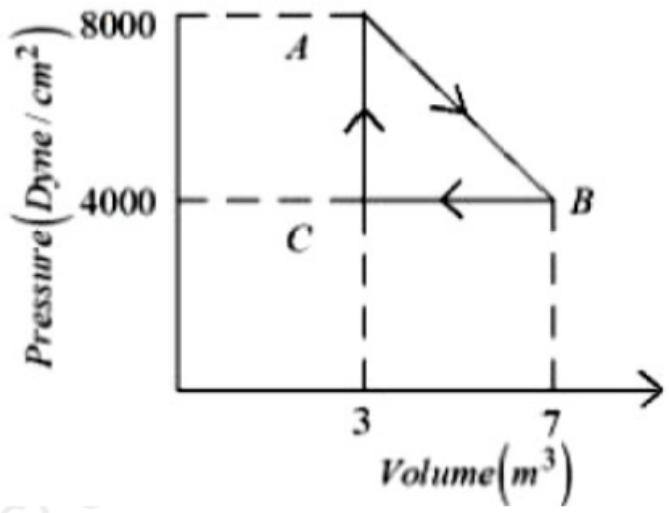
$\gamma = -3 + 3\gamma$

$3 = 2\gamma$

$\gamma = \frac{3}{2}$

Question53

A thermodynamic system is taken from an original state A to an intermediate state B by a linear process as shown in the figure. It's volume is then reduced to the original value from B to C by an isobaric process. The total work done by the gas from A to B and B to C would be :



[29-Jan-2024 Shift 1]

Options:

A.

33800J

B.

2200J

C.

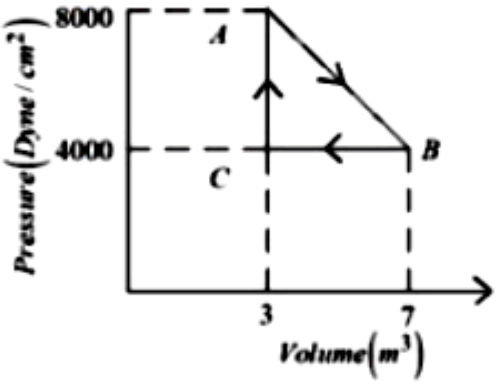
800J

D.

1200J

Answer: C

Solution:



$$\text{Work done} \quad AB = \frac{1}{2}(8000+6000)\ \text{Dyne}/\text{cm}^2 \times 4\text{m}^3 = (6000\,\text{Dyne}/\text{cm}^2) \times 4\text{m}^3$$

$$\text{Work done}\ BC = -(4000\,\text{Dyne}/\text{cm}^2) \times 4\text{m}^3$$

$$\text{Total work done} = 2000\ \text{Dyne}/\text{cm}^2 \times 4\text{m}^3$$

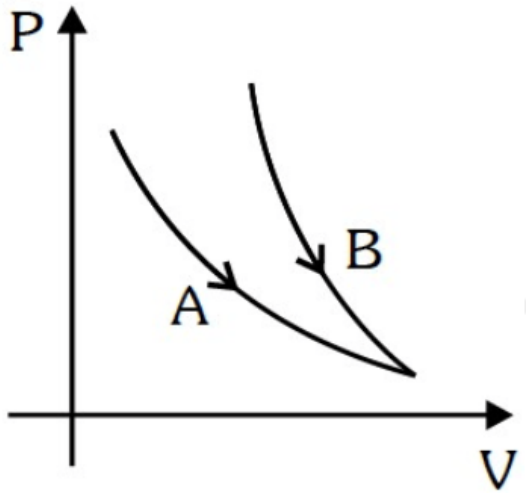
$$= 2 \times 10^3 \times \frac{1}{10^5}\frac{\text{N}}{\text{cm}^2} \times 4\text{m}^3$$

$$= 2 \times 10^{-2} \times \frac{\text{N}}{10^{-4}\text{m}^2} \times 4\text{m}^3$$

$$= 2 \times 10^2 \times 4\,\text{Nm} = 800\text{J}$$

Question54

Choose the correct statement for processes A & B shown in figure.



[30-Jan-2024 Shift 2]

Options:

A.

$PV^{\gamma} = k$ for process B and $PV = k$ for process A.

B.

$PV = k$ for process B and A.

C.

$\frac{P^{\gamma-1}}{T^{\gamma}} = k$ for process B and $T = k$ for process A.

D.

$\frac{T^{\gamma}}{P^{\gamma-1}} = k$ for process A and $PV = k$ for process B.

Answer: 0

Solution:

Steeper curve (B) is adiabatic

Adiabatic $\Rightarrow PV^{\gamma} = \text{const.}$

Or $P\left(\frac{T}{P}\right)^{\gamma} = \text{const.}$

$$\frac{T^{\gamma}}{P^{\gamma-1}} = \text{const.}$$

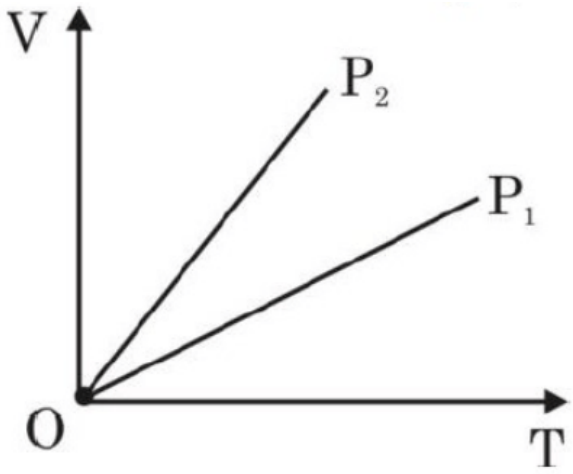
Curve (A) is isothermal

$T = \text{const.}$

$PV = \text{const.}$

Question55

The given figure represents two isobaric processes for the same mass of an ideal gas, then



[31-Jan-2024 Shift 1]

Options:

A.

$P_2 \geq P_1$

B.

$P_2 > P_1$

C.

$P_1 = P_2$

D.

$P_1 > P_2$

Answer: D

Solution:

$$PV = nRT$$

$$V = \left(\frac{nR}{P}\right)T$$

$$\text{Slope} = \frac{nR}{P}$$

$$\text{Slope} \propto \frac{1}{P}$$

$$(\text{Slope})_2 > (\text{Slope})_1$$

$$P_2 < P_1$$

Question56

The pressure and volume of an ideal gas are related as $PV^{3/2} = K$ (Constant). The work done when the gas is taken from state A(P_1, V_1, T_1) to state B(P_2, V_2, T_2) is :

[1-Feb-2024 Shift 1]

Options:

A.

$2(P_1V_1 - P_2V_2)$

B.

$2(P_2V_2 - P_1V_1)$

C.

$2(\sqrt{P_1}V_1 - \sqrt{P_2}V_2)$

D.

$2(P_2\sqrt{V_2} - P_1\sqrt{V_1})$

Answer: B

Solution:

For $PV^x =$ constant

If work done by gas is asked then

$$W = \frac{nR\Delta T}{1-x}$$

Here $x = \frac{3}{2}$

$$\therefore W = \frac{P_2V_2 - P_1V_1}{-\frac{1}{2}}$$

$= 2(P_1V_1 - P_2V_2)$..... Option (1) is correct

If work done by external is asked then $W = -2(P_1V_1 - P_2V_2)$..... Option (2) is correct

---

Question57

A diatomic gas ($\gamma = 1.4$) does 200J of work when it is expanded isobarically. The heat given to the gas in the process is :

[1-Feb-2024 Shift 2]

Options:

A.

850J

B.

800J

C.

600J

D.

700J

Answer: D

Solution:

$$\gamma = 1 + \frac{2}{f} = 1.4 \Rightarrow \frac{2}{f} = 0.4$$

$$\Rightarrow f = 5$$

$$W = nR\Delta T = 200J$$

$$Q = \left(\frac{f+2}{2}\right) nR\Delta T$$

$$= \frac{7}{2} \times 200 = 700J$$

Question58

1g of a liquid is converted to vapour at 3×10^5 Pa pressure. If 10% of the heat supplied is used for increasing the volume by $1600cm^3$ during this phase change, then the increase in internal energy in the process will be :
[24-Jan-2023 Shift 1]

Options:

A. 4320J

B. 432000J

C. 4800J

D. 4.32×10^8J

Answer: A

Solution:

Solution:
Work done $= P \Delta V$
$= 3 \times 10^5 \times 1600 \times 10^{-6}$
$= 480$J
Only 10% of heat is used in work done.
Hence $\Delta Q = 4800$J
The rest goes in internal energy, which is 90% of heat.
Change in internal energy $= 0.9 \times 4800 = 4320$J

Question59

Let γ_1 be the ratio of molar specific heat at constant pressure and molar specific heat at constant volume of a monoatomic gas and γ_2 be the similar ratio of diatomic gas. Considering the diatomic gas molecule as a rigid rotator, the ratio, $\frac{\gamma_1}{\gamma_2}$ is
[24-Jan-2023 Shift 2]

Options:

A. $\frac{27}{35}$

B. $\frac{35}{27}$

C. $\frac{25}{21}$

D. $\frac{21}{25}$

Answer: C

Solution:

Solution:

For monoatomic gas $\gamma_1 = \frac{5}{3}$

For diatomic gas at low temperatures

$\gamma_2 = \frac{7}{5}$

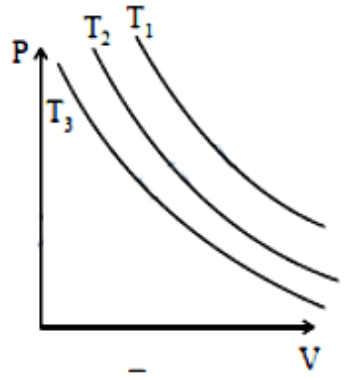
$\therefore \frac{\gamma_1}{\gamma_2} = \frac{\frac{5}{3}}{\frac{7}{5}} = \frac{25}{21}$

Question60

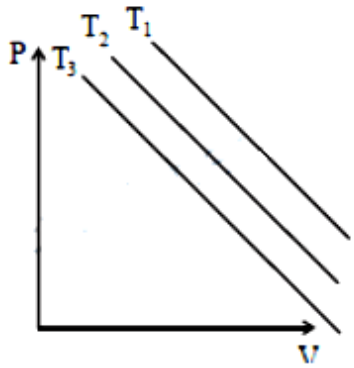
In an Isothermal change, the change in pressure and volume of a gas can be represented for three different temperature; $T_3 > T_2 > T_1$ as : [24-Jan-2023 Shift 2]

Options:

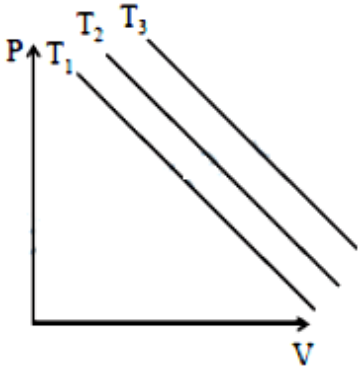
A.



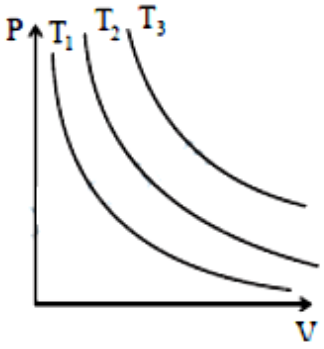
B.



C.



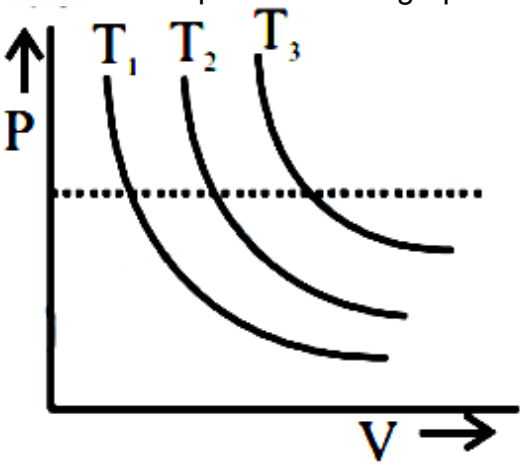
D.



Answer: D

Solution:

Solution:
For isothermal process $P-V$ graph is rectangular hyperbola



As dotted line is isobaric line which implies $T_3 > T_2 > T_1$ as volume is increasing.

Question61

A Carnot engine with efficiency 50% takes heat from a source at 600K. In order to increase the efficiency to 70%, keeping the

temperature of sink same, the new temperature of the source will be : [25-Jan-2023 Shift 1]

Options:

A. 360K

B. 1000K

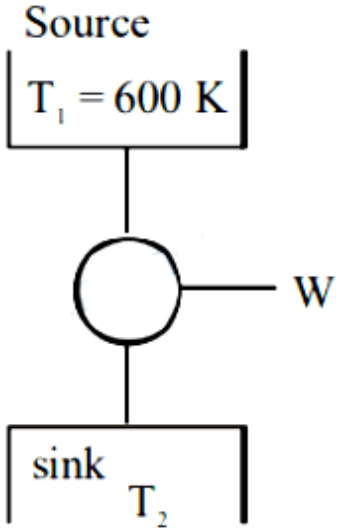
C. 900K

D. 300K

Answer: B

Solution:

Solution:



Initially $\eta = \frac{1}{2}$

But $\eta = 1 - \frac{T_2}{T_1}$

$\therefore \frac{1}{2} = 1 - \frac{T_2}{600}$

$\Rightarrow \frac{T_2}{600} = \frac{1}{2}$

Now efficiency is increased to 70% and $T_2 = 300$ K, Let temp of source $T_1 = T$

$\Rightarrow \frac{7}{10} = 1 - \frac{300}{T}$

$\Rightarrow \frac{300}{T} = 1 - \frac{7}{10}$

$\Rightarrow \frac{300}{T} = \frac{3}{10} \quad \therefore T_2 = 300\text{K}$

Question62

A bowl filled with very hot soup cools from 98°C to 86°C in 2 minutes when the room temperature is 22°C. How long it will take to cool from 75°C to 69°C ?
[25-Jan-2023 Shift 1]

Options:

A. 2 minutes

B. 1.4 minutes

C. 0.5 minute

D. 1 minute

Answer: B

Solution:

Solution:

$$\frac{\Delta Q}{\Delta t} = -K(T - T_0)$$

$$\frac{\Delta Q}{\Delta t} = -K(T_{avg} - T_0)$$

(i) $\frac{ms \times 12}{2} = -K\left(\frac{98+86}{2} - 22\right)$

$$6 = -\frac{K}{ms}\left[\frac{98+86}{2} - 22\right]$$

$$6 = -\frac{K}{ms}[70] \ldots\ldots\ldots \text{(i)}$$

(ii) $\frac{ms \times 6}{\Delta t} = -K\left(\frac{75+69}{2} - 22\right)$

$$\frac{6}{\Delta t} = -\frac{K}{ms}(50) \ldots\ldots\ldots\ldots \text{(II)}$$

(ii) ÷ (i)

$$\frac{6}{\Delta t(6)} = \frac{50}{70}$$

$$\Delta t = \frac{7}{5} = 1.4 \text{ min}$$

Question63

Match List I with List II :

List I	List II
A. IsothermalProcess	I. Work done by the gas decreases internal energy
B. Adiabatic Process	II. No change in internal energy
C. Isochoric Process	III. The heat absorbed goes partly to increase internal energy and partly to do work
D. Isobaric Process	IV. No work is done on or by the gas

Choose the correct answer from the options given below : [25-Jan-2023 Shift 2]

Options:

A. A-II, B-I, C-III, D-IV

B. A-II, B-I, C-IV, D-III

C. A-I, B-II, C-IV, D-III

D. A-I, B-II, C-III, D-IV

Answer: A

Solution:

Solution:
$\Delta U = nC_v \Delta T$
For isothermal process T is constant
So $\Delta U = 0$
$A \longrightarrow II$
Adiabatic process
$\Delta Q = 0$
$\Delta Q = \Delta U + \Delta W$
$\Delta U = -\Delta W$
Work done by gas is positive
So ΔU is negative
$B \longrightarrow I$
For Isochoric process $\Delta W = 0$
$C \longrightarrow IV$
For Isobaric process
$\Delta W = P \Delta V \neq 0$
$\Delta U = nC_V \Delta T \neq 0$
Heat absorbed goes partly to increase internal energy and partly do work.

Question64

According to law of equipartition of energy the molar specific heat of a diatomic gas at constant volume where the molecule has one additional vibrational mode is :-
[25-Jan-2023 Shift 2]

Options:

A. $\frac{9}{2}R$

B. $\frac{5}{2}R$

C. $\frac{3}{2}R$

D. $\frac{7}{2}R$

Answer: D

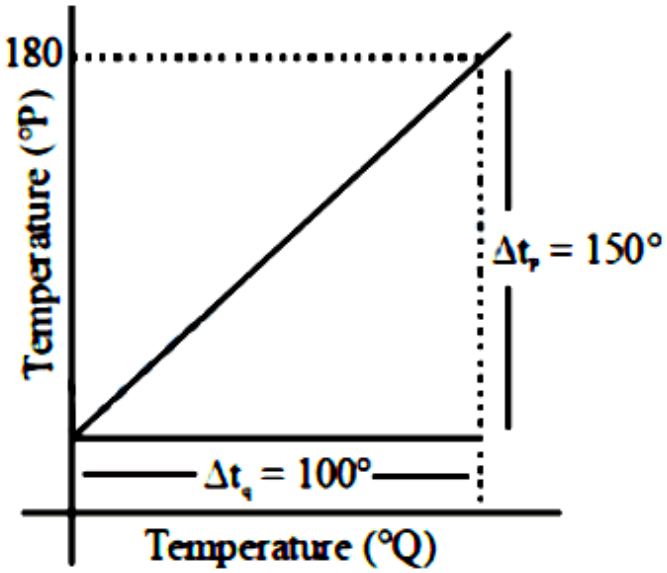
Solution:

Solution:
Diatomic gas molecules have three translational degree of freedom, two rotational degree of freedom & it is given that it has one vibrational mode so there are two additional degree of freedom corresponding to one vibrational mode, so total degree of freedom $= 7$

$C_v = \frac{fR}{2} = \frac{7R}{2}$

Question65

The graph between two temperature scales P and Q is shown in the figure. Between upper fixed point and lower fixed point there are 150 equal divisions of scale P and 100 divisions on scale Q. The relationship for conversion between the two scales is given by :



[25-Jan-2023 Shift 2]

Options:

A. $\frac{t_Q}{150} = \frac{t_P - 180}{100}$

B. $\frac{t_Q}{100} = \frac{t_P - 30}{150}$

C. $\frac{t_P}{180} = \frac{t_Q - 40}{100}$

D. $\frac{t_P}{100} = \frac{t_Q - 180}{150}$

Answer: B

Solution:

Solution:

$$\frac{\text{reading on scale} - \text{Lower fixed point}}{\text{upper fixed point-lower fixed point}} = \text{constant}$$

$$\frac{t_P - 30}{180 - 30} = \frac{t_Q - 0}{100 - 0}$$

$$\frac{t_P - 30}{150} = \frac{t_Q}{100}$$

Question66

A bicycle tyre is filled with air having pressure of 270 kPa at 27°C. The approximate pressure of the air in the tyre when the temperature

increases to 36°C is
[29-Jan-2023 Shift 1]

Options:

A. 270 kPa

B. 262 KPa

C. 278 kPa

D. 360 kPa

Answer: C

Solution:

Solution:

Taking volume constant : $\frac{P_1}{T_1} = \frac{P_2}{T_2}$

$\Rightarrow P_2 = \frac{P_1}{T_1} \times T_2 = \frac{270 \times (309)}{300}$

$= 278\,\text{kPa}$

Question67

Given below are two statements. One is labelled as Assertion A and the other is labelled as Reason R.
Assertion A : If dQ and dW represent the heat supplied to the system and the work done on the system respectively. Then according to the first law of thermodynamics d Q = d U − d W .
Reason R : First law of thermodynamics is based on law of conservation of energy.
In the light of the above statements, choose the correct answer from the option given below :
[29-Jan-2023 Shift 1]

Options:

A. A is correct but R is not correct

B. A is not correct but R is correct

C. Both A and R are correct and R is the correct explanation of A

D. Both A and R are correct but R is not the correct explanation of A

Answer: C

Solution:

Solution:
First law of thermodynamics is based on law of conservation of energy and it can be written as $dQ = dU - dW$.
where dW is work done on the system

Question68

A body cools from 60°C to 40°C in 6 minutes. If, temperature of surroundings is 10°C. Then, after the next 6 minutes, its temperature will be °C.
[29-Jan-2023 Shift 1]

Answer: 28

Solution:

Solution:
By average form of Newton's law of cooling

$$\frac{20}{6} = k(50 - 10) \ldots \text{(i)}$$

$$\frac{40 - T}{6} = K\left(\frac{40 + T}{2} - 10\right) \ldots \text{(ii)}$$

From equation (i) and (ii)

$$\frac{20}{40 - T} = \frac{40}{10 + T/2}$$

$$10 + \frac{T}{2} = 80 - 2T$$

$$\frac{5T}{2} = 70 \Rightarrow T = 28^{\circ}C$$

Question69

Heat energy of 184 kJ is given to ice of mass 600g at $-12^{\circ}C$, Specific heat of ice is $2222.3 Jkg^{-1}{}^{\circ}C^{-1}$ and latent heat of ice in 336 kJ/kg^{-1}

(A) Final temperature of system will be $0^{\circ}C$.

(B) Final temperature of the system will be greater than $0^{\circ}C$.

(C) The final system will have a mixture of ice and water in the ratio of 5 : 1.

(D) The final system will have a mixture of ice and water in the ratio of 1 : 5.

(E) The final system will have water only.

Choose the correct answer from the options given below:

[29-Jan-2023 Shift 2]

Options:

A. A and D only

B. B and D only

C. A and E only

D. A and C only

Answer: A

Solution:

Solution:

$\Delta Q = 184 \times 10^3$

$m = 0.600\,kg$ at $-12^{\circ}C$

$S = 222.3 J/kg/^{\circ}C$

$L = 336 \times 10^3 J/kg$

$Q_1 = 0.600 \times 2222.3 \times 12 = 16000.56J$

Remaining heat $\Delta Q_1 = 184000 - 16000.56$

$= 167999.44J$

For meeting at $0^{\circ}C$

$\Delta Q_2 = 0.600 \times 336000 = 201600J$ needed

$\therefore$ 100% ice is not melted

Amount of ice melted

$167999.44 = m \times 336000 = 0.4999\,kg$

$\therefore$ mass of water $= 0.4999\,kg$

Mass of ice $= 0.1001$

$\therefore$ Ratio $= \frac{0.1001}{0.4999} \approx 1 : 5$

Question70

Heat is given to an ideal gas in an isothermal process.
A. Internal energy of the gas will decrease.
B. Internal energy of the gas will increase.
C. Internal energy of the gas will not change.
D. The gas will do positive work.
E. The gas will do negative work.
Choose the correct answer from the options given below:
[30-Jan-2023 Shift 1]

Options:

A. A and E only

B. B and D only

C. C and E only

D. C and D only

Answer: D

Solution:

Solution:
Sol. $dQ = dU + dW \Rightarrow dU = nC_V\, dT$
$dU = 0$ (for isothermal)
$\therefore$ U = constant
Also $dQ > 0$ (supplied)
Hence $dW > 0$

Question71

Given below are two statements : one is labelled as Assertion A and the other is labelled as Reason R.
Assertion A : Efficiency of a reversible heat engine will be highest at $-273^{\circ}C$ temperature of cold reservoir.
Reason R : The efficiency of Carnot's engine depends not only on temperature of cold reservoir but it depends on the temperature of

hot reservoir too and is given as $\eta = \left(1 - \frac{T_2}{T_1}\right)$.

In the light of the above statements, choose the correct answer from the options given below :
[30-Jan-2023 Shift 2]

Options:

A. A is true but R is false

B. Both A and R are true but R is NOT the correct explanation of A

C. A is false but R is true

D. Both A and R are true and R is the correct explanation of A

Answer: D

Solution:

Solution:
Both A and R are true and R is the correct explanation of A

Question72

The correct relation between $\gamma = \frac{C_p}{c_v}$ and temperature T is:
[31-Jan-2023 Shift 1]

Options:

A. $\gamma \propto \frac{1}{\sqrt{T}}$

B. $\gamma \propto T^{\circ}$

C. $\gamma \propto \frac{1}{T}$

D. $\gamma \propto T$

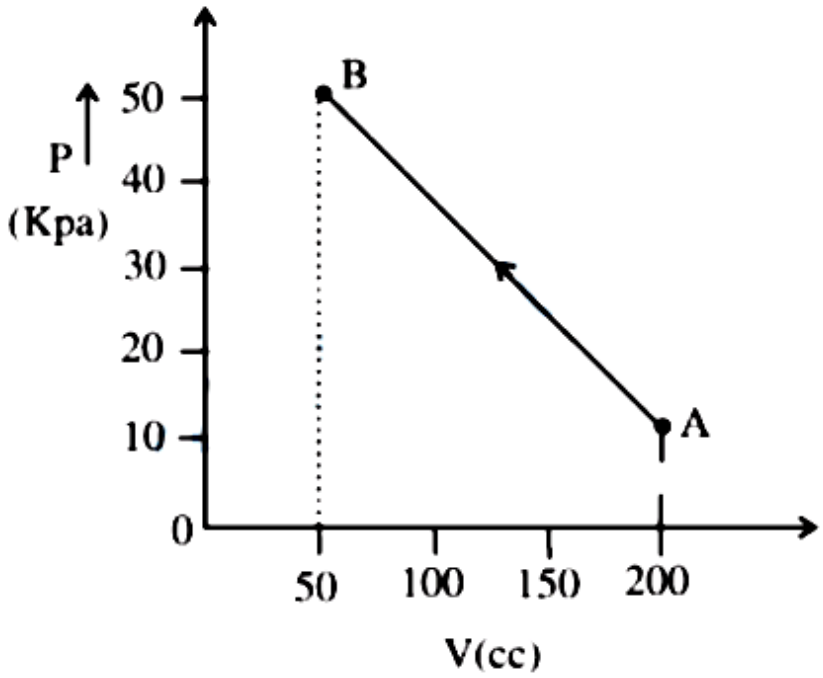
Answer: B

Solution:

Solution:
γ is independent of temperature
Option 2

Question73

The pressure of a gas changes linearly with volume from A to B as shown in figure. If no heat is supplied to or extracted from the gas then change in the internal energy of the gas will be



[31-Jan-2023 Shift 1]

Options:

A. 6J

B. Zero

C. −4.5J

D. 4.5J

Answer: D

Solution:

Solution:
As $\Delta q = 0$
$\Delta u = -W$
$W = \int PdV$

$\Delta u = -W = 30 \times 10^3 \times 150 \times 10^{-6}$
$= 4500 \times 10^{-3}$
$= 4.5J$

Question74

A hypothetical gas expands adiabatically such that its volume changes from 08 litres to 27 litres. If the ratio of final pressure of the gas to initial pressure of the gas is $\frac{16}{81}$. Then the ratio of $\frac{Cp}{Cv}$ will be. [31-Jan-2023 Shift 1]

Options:

A. 3/1

B. 4/3

C. 1/2

D. 3/2

Answer: A

Solution:

Solution:
Let γ be the ratio of $\frac{C_p}{C_v}$
Then for adiabatic process
$PV^{\gamma} = \text{Constant}$
$\Rightarrow \frac{P_i}{P_f} = \left(\frac{V_f}{V_i}\right)^{\gamma}$
$\Rightarrow \frac{81}{16} = \left(\frac{27}{8}\right)^{\gamma}$
$\Rightarrow \gamma = \frac{4}{3}$

Question75

Heat energy of 735J is given to a diatomic gas allowing the gas to expand at constant pressure. Each gas molecule rotates around an internal axis but do not oscillate. The increase in the internal energy

of the gas will be:
[31-Jan-2023 Shift 2]

Options:

A. 525J

B. 441J

C. 572J

D. 735J

Answer: A

Solution:

Solution:
$\Delta Q = nC_P \Delta T = 735J$
$\Rightarrow \frac{5nR \Delta T}{2} = 735J$
$\Delta U = nC_V \Delta T = \frac{3}{2}(nR \Delta T) = \frac{3}{2} \times \frac{2}{5} \times 735$
$= 441J$

Question76

A sample of gas at temperature T is adiabatically expanded to double its volume. The work done by the gas in the process is (. given, $\gamma = \frac{3}{2}$) :
[1-Feb-2023 Shift 1]

Options:

A. $W = TR[\sqrt{2} - 2]$

B. $W = \frac{T}{R}[\sqrt{2} - 2]$

C. $W = \frac{R}{T}[2 - \sqrt{2}]$

D. $W = RT[2 - \sqrt{2}]$

Answer: D

Solution:

Solution:

$$T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$$

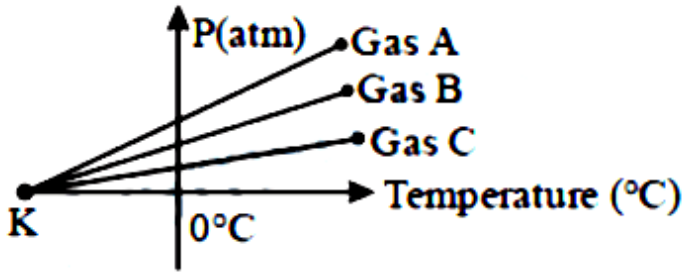
$$T V^{1/2} = T_2 (2V)^{1/2}$$

$$T_2 = \frac{T}{\sqrt{2}}$$

$$W = \frac{R(T_1 - T_2)}{\gamma - 1} = \frac{R\left(T - \frac{T}{\sqrt{2}}\right)}{\frac{1}{2}} = RT(2 - \sqrt{2})$$

Question77

For three low density gases A, B, C pressure versus temperature graphs are plotted while keeping them at constant volume, as shown in the figure.



The temperature corresponding to the point ' K ' is:
[1-Feb-2023 Shift 2]

Options:

A. $-273^{\circ}C$

B. $-100^{\circ}C$

C. $-373^{\circ}C$

D. $-40^{\circ}C$

Answer: A

Solution:

Solution:
For isochoric process

$$\frac{P}{T} = n\frac{R}{V} = \text{constan t}$$

$$P = \frac{nR}{V}(t + 273)$$

If $P = 0 \Rightarrow t = -273^{\circ}C$

Question78

A Carnot engine operating between two reservoirs has efficiency $\frac{1}{3}$. When the temperature of cold reservoir raised by x, its efficiency decreases to $\frac{1}{6}$. The value of x, if the temperature of hot reservoir is 99°C, will be:
[1-Feb-2023 Shift 2]

Options:

A. 16.5K

B. 33K

C. 66K

D. 62K

Answer: D

Solution:

Solution:

$$T_H = 99^{\circ}C = 99 + 273$$

$$= 372K$$

$$1 - \frac{T_C}{T_H} = \frac{1}{3}$$

$$1\ \frac{T_C}{T_H} = \frac{2}{3}\ (1) \Rightarrow T_C = \frac{2}{3} \times 372$$

$$= 2 \times 124 = 248K$$

$$1 - \frac{T_C + X}{T_H} = \frac{1}{6}$$

$$\frac{5}{6} = \frac{T_C + X}{T_H}$$

$$\frac{5}{6} = \frac{248 + X}{372}$$

$248 + X = 5 \times 62$
$X = 310 - 248 = 62K$

Question79

A source supplies heat to a system at the rate of 1000W. If the system performs work at a rate of 200W. The rate at which internal energy of the system increase is
[6-Apr-2023 shift 1]

Options:

A. 500W

B. 600W

C. 800W

D. 1200W

Answer: C

Solution:

Solution:
From Ist law of thermodynamics,
$dQ = dU + dW$
Also, we can write this as, $\frac{dQ}{dt} = \frac{dU}{dt} + \frac{dW}{dt}$

$\Rightarrow 1000W = \frac{dU}{dt} + 200W$

$\Rightarrow \frac{dU}{dt} = 800W$

Question80

Given below are two statements:
Statement I : If heat is added to a system, its temperature must increase.
Statement II : If positive work is done by a system in a thermodynamic process, its volume must increase. In the light of the above statements, choose the correct answer from the options given

below
[8-Apr-2023 shift 1]

Options:

A. Both Statement I and Statement II are true

B. Statement I is true but Statement II is false

C. Both Statement I and Statement II are false

D. Statement I is false but Statement II is true

Answer: D

Solution:

Solution:
St I False
Ex. in isothermal process temp. is constant but heat can be added. ST II True
$w = \int PdV$
If volume increases the $w = +$ ve

Question81

Work done by a Carnot engine operating between temperatures $127^{\circ}C$ and $27^{\circ}C$ is 2 kJ. The amount of heat transferred to the engine by the reservoir is:
[8-Apr-2023 shift 2]

Options:

A. 2 kJ

B. 4 kJ

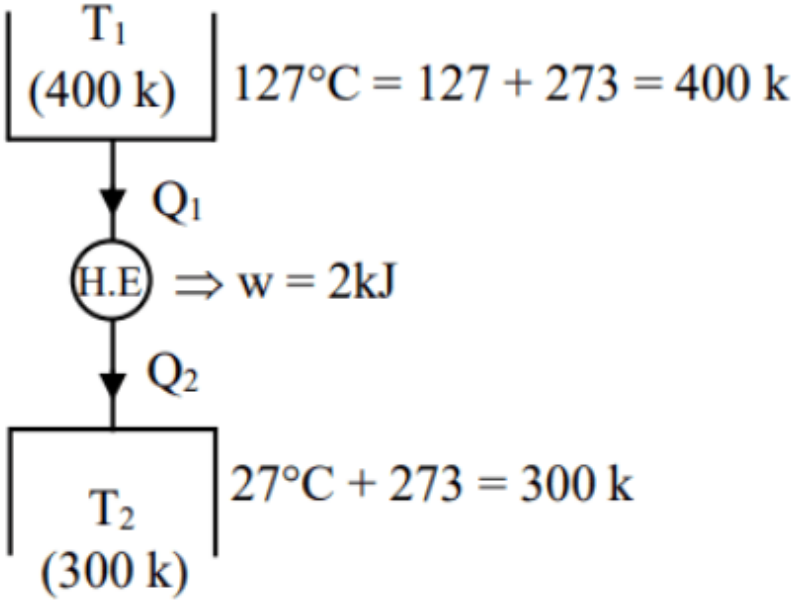
C. 2.67 kJ

D. 8 kJ

Answer: D

Solution:

Solution:



$n = 1 - \frac{300}{400} = \frac{1}{4}$

$n = \frac{w}{Q_1} = \frac{1}{4} \Rightarrow Q_1 = 8\,kJ$

Question82

Consider two containers A and B containing monoatomic gases at the same Pressure (P), Volume (V) and Temperature (T). The gas in A is compressed isothermally to $\frac{1}{8}$ of its original volume while the gas in B is compressed adiabatically to $\frac{1}{8}$ of its original volume. The ratio of final pressure of gas in B to that of gas in A is
[10-Apr-2023 shift 1]

Options:

A. 8

B. 4

C. $\frac{1}{8}$

D. $8^{\frac{3}{2}}$

Answer: B

Solution:

Solution:
By Isothermal Process for (A)

$$P_1V_1 = P_2V_2$$

$$PV = P_2\frac{V}{8}$$

$$P_2 = 8P$$

For B adiabatically $\gamma_{mono} = \frac{5}{3}$

$$P_1V_1^{\gamma} = P_2V_2^{\gamma}$$

$$PV^{5/3} = P_2\left(\frac{V}{8}\right)^{5/3}$$

$$P_2 = (8)^{5/3}P$$

$$\frac{P_2}{P_1} = \frac{8^{5/3}}{8P} = (8)^{\frac{2}{3}} = 4$$

Question83

A gas is compressed adiabatically, which one of the following statement is NOT true.
[10-Apr-2023 shift 2]

Options:

A. There is no change in the internal energy

B. The temperature of the gas increases.

C. The change in the internal energy is equal to the work done on the gas

D. There is no heat supplied to the system

Answer: A

Solution:

Solution:
In Adiabatic process, $\Delta Q = 0$
If gas is compressed, then w (by gas) $\neq 0$
Therefore by 1^{st} law

$$\Delta Q = \Delta u + w$$

$$0 = \Delta u + w$$

$$\Delta u = -w \neq 0$$

It implies in adiabatic compression, internal energy of gas changes.

Question84

The Thermodynamic process, in which internal energy of the system remains constant is
[11-Apr-2023 shift 2]

Options:

A. Isobaric

B. Isochoric

C. Adiabatic

D. Isothermal

Answer: D

Solution:

Solution:
$\Delta U = nC_V \Delta T$, for all process
For isothermal process, $\Delta T = 0$
So, $\Delta U = 0$
That means internal energy of system remains constant.

Question85

An engine operating between the boiling and freezing points of water will have
A. efficiency more than 27%
B. efficiency less than the efficiency of a Carnot engine operating between the same two temperatures.
C. efficiency equal to 27%
D. efficiency less than 27%
Choose the correct answer from the options given below :
[12-Apr-2023 shift 1]

Options:

A. B and C only

B. B and D only

C. B, C and D only

D. A and b only

Answer: B

Solution:

Solution:
Engine is operating between FP and BP of water.
We asked to find efficiency :

$T_1 = 100^\circ C \Rightarrow 100 + 273 = 373K$

$T_2 = 0^\circ C \Rightarrow 0 + 273 = 273K$

We know

$$\eta = 1 - \frac{T_2}{T_1}$$

$$\eta = 1 - \frac{273}{373}$$

$$\eta = \frac{373 - 273}{373} = \frac{100}{373}$$

$\eta = 0.268$

and

$\eta\% = 0.268 \times 100$

$\eta\% = 26.8\%$

Question86

The initial pressure and volume of an ideal gas are P_o and V_0. The final pressure of the gas when the gas is suddenly compressed to volume $\frac{V_o}{4}$ will be :
(Given γ = ratio of specific heats at constant pressure and at constant volume)
[13-Apr-2023 shift 2]

Options:

A. $P_0(4)^{\frac{1}{y}}$

B. $4P_0$

C. P_0

D. $P_0(4)^{\gamma}$

Answer: D

Solution:

Solution:
As, gas in suddenly compressed, the process is adiabatic
So equation of gas for adiabatic process is:

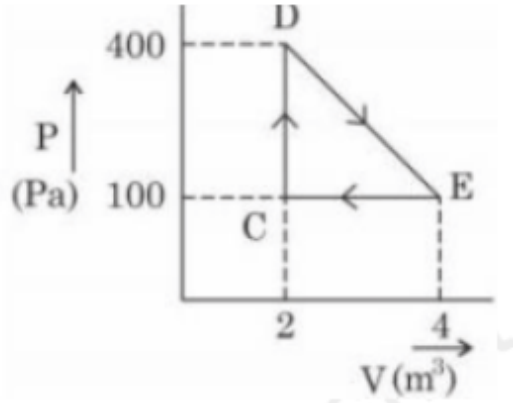
$$PV^{\gamma} = \text{constant}$$

$$P_0V_0^{\gamma} = P_2\left(\frac{V_0}{4}\right)^{\gamma}$$

$$P_2 = P_0(4)^{\gamma}$$

Question87

A thermodynamic system is taken through cyclic process. The total work done in the process is :



[15-Apr-2023 shift 1]

Options:

A. 100J

B. 300J

C. 200J

D. Zero

Answer: B

Solution:

Solution:

Work done = Area of graph

$W = \frac{1}{2}(400-100)(4-2)$

$W = 300J$

Question88

A Carnot engine whose heat sinks at 27°C, has an efficiency of 25%. By how many degrees should the temperature of the source be changed to increase the efficiency by 100% of the original efficiency? [24-Jun-2022-Shift-1]

Options:

A. Increases by $18^{\circ}C$

B. Increases by $200^{\circ}C$

C. Increases by $120^{\circ}C$

D. Increases by $73^{\circ}C$

Answer: B

Solution:

Solution:

Initially : $\frac{1}{4} = 1 - \frac{300}{T_H}$

$\Rightarrow T_H = 400K$

Finally : Efficiency becomes $\frac{1}{2}$

$\Rightarrow \frac{1}{2} = 1 - \frac{300}{T_H'}$

$\Rightarrow T_H' = 600K$

$\Rightarrow$ Temperature of the source increases by $200^{\circ}C$.

Question89

A Carnot engine takes 5000 kcal of heat from a reservoir at 727°C and gives heat to a sink at 127°C. The work done by the engine is

[24-Jun-2022-Shift-2]

Options:

A. $3 \times 10^6 J$

B. Zero

C. $12.6 \times 10^6 J$

D. $8.4 \times 10^6 J$

Answer: C

Solution:

Solution:

Efficiency $\eta = 1 - \frac{T_L}{T_H}$

$= 1 - \frac{400}{1000} = 0.6$

$\Rightarrow 0.6 = \frac{W}{Q}$

$\Rightarrow W = 0.6Q = 3000\,\text{kcal} = 12.6 \times 10^6 J$

Question90

A monoatomic gas performs a work of $\frac{Q}{4}$ where Q is the heat supplied to it. The molar heat capacity of the gas will be____ R during this transformation. Where R is the gas constant.
[24-Jun-2022-Shift-2]

Answer: 2

Solution:

Solution:

By 1^{st} law,

$\Delta U = \Delta Q - \frac{\Delta Q}{4} = \frac{3}{4}\Delta Q$

$\Rightarrow nC_v \Delta T = \frac{3}{4} nC \Delta T$

$\Rightarrow C = \frac{4C_v}{3} = 2R$

Question91

The efficiency of a Carnot's engine, working between steam point and ice point, will be :
[26-Jun-2022-Shift-1]

Options:

A. 26.81%

B. 37.81%

C. 47.81%

D. 57.81%

Answer: A

Solution:

Solution:

$\eta = 1 - \frac{T_2}{T_1} = 1 - \frac{273}{373}$

$= 0.26809$

$\approx 26.81\%$

Question92

A thermally insulated vessel contains an ideal gas of molecular mass M and ratio of specific heats 1.4. Vessel is moving with speed v and is suddenly brought to rest. Assuming no heat is lost to the surrounding and vessel temperature of the gas increases by :
(R = universal gas constant)
[26-Jun-2022-Shift-1]

Options:

A. $\frac{M v^2}{7R}$

B. $\frac{M v^2}{5R}$

C. 2 $\frac{M v^2}{7R}$

D. 7 $\frac{M v^2}{5R}$

Answer: B

Solution:

Solution:
Let there be n moles of gas

$E_{loss} = E_{gain}$

$\frac{1}{2}(nM)v^2 = nC_v \Delta T$

$\frac{1}{2}M v^2 = C_v \Delta T$

here, $\gamma = 1.4 = \frac{7}{5}$ i.e. diatomic gas

$\therefore C_v = \frac{5R}{2}$

Now, $\frac{1}{2}M v^2 = \frac{5R}{2} \Delta T$

$\Delta T = \frac{M v^2}{5R}$

Question93

A heat engine operates with the cold reservoir at temperature 324K. The minimum temperature of the hot reservoir, if the heat engine takes 300J heat from the hot reservoir and delivers 180J heat to the cold reservoir per cycle, is _____K.
[26-Jun-2022-Shift-2]

Answer: 540

Solution:

Solution:

$$\left(1-\frac{324}{T_H}\right)=\frac{300-180}{300}$$

$$1-\frac{2}{5}=\frac{324}{T_H}$$

$$T_H=\frac{324\times 5}{3}=540$$

Question94

In a carnot engine, the temperature of reservoir is 527°C and that of sink is 200K. If the work done by the engine when it transfers heat from reservoir to sink is 12000 kJ, the quantity of heat absorbed by the engine from reservoir is ____$\times 10^6$J.
[27-Jun-2022-Shift-1]

Answer: 16

Solution:

Solution:

$$\eta=1-\frac{T_2}{T_1}$$

$$=1-\frac{200}{800}=\frac{3}{4}$$

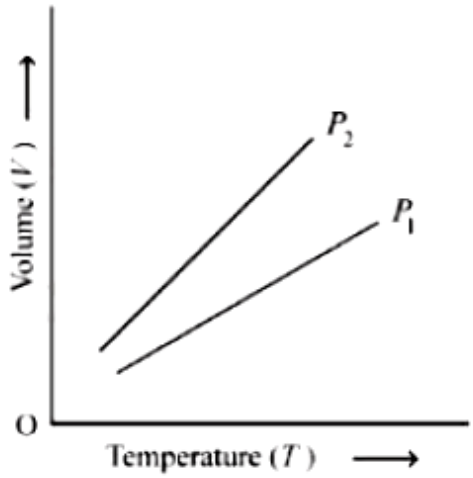
$$\therefore\eta=\frac{W}{Q_1}$$

$$\Rightarrow\frac{3}{4}=\frac{12000\times 10^3}{Q_1}$$

$$\Rightarrow Q_1=16\times 10^6 J$$

Question95

For a perfect gas, two pressures P_1 and P_2 are shown in figure. The graph shows:



[27-Jun-2022-Shift-2]

Options:

A. $P_1 > P_2$

B. $P_1 < P_2$

C. $P_1 = P_2$

D. Insufficient data to draw any conclusion

Answer: A

Solution:

Solution:
As per ideal gas equation, $V = \frac{nR}{P}T$
$\Rightarrow$ Slope of V-T graph is inversely proportional to P.
As $m_2 > m_1 \Rightarrow P_1 > P_2$

Question96

A diatomic gas ($\gamma = 1.4$) does 400J of work when it is expanded isobarically. The heat given to the gas in the process is_____ J. [27-Jun-2022-Shift-2]

Answer: 1400

Solution:

Solution:
$W = nR\,\Delta T = 400J$
$\therefore \Delta Q = nC_P\,\Delta T$
$= n \times \frac{7}{2}R \times \Delta T = \frac{7}{2} \times (400) = 1400$

Question97

The total internal energy of two mole monoatomic ideal gas at temperature T = 300K will be_____J. (Given R = 8.31 J/mol . K) [28-Jun-2022-Shift-1]

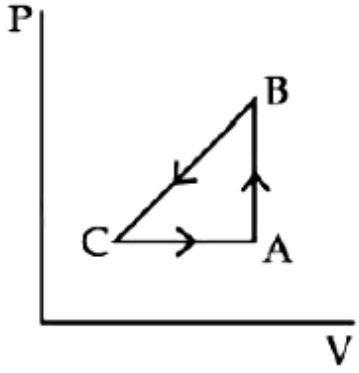
Answer: 7479

Solution:

Solution:
$U = 2\left(\frac{3}{2}R\right)300$
$= 3 \times 8.31 \times 300$
$= 7479J$

Question98

A sample of an ideal gas is taken through the cyclic process ABCA as shown in figure. It absorbs, 40J of heat during the part AB, no heat during BC and rejects 60J of heat during CA. A work of 50J is done on the gas during the part BC. The internal energy of the gas at A is 1560J. The work done by the gas during the part CA is :



[28-Jun-2022-Shift-2]

Options:

A. 20J

B. 30J

C. −30J

D. −60J

Answer: B

Solution:

Solution:
$\Delta U_{AB} = 40J$ as process is isochoric.
$\Delta U_{BC} = +50 (W_{BC} = -50J)$
$U_C = U_A + \Delta U_{AB} + \Delta U_{BC} = 1650$
For CA process,
$Q_{CA} = -60J$
$\Delta U_{CA} + W_{CA} = -60$
$-90 + W_{CA} = -60$
$\Rightarrow W_{CA} = +30J$
The graph given is inconsistent with the statement BC may be adiabatic and CA cannot be like isobaric as shown, as increasing volume while rejecting heat at same time.

Question99

A cylinder of fixed capacity of 44.8 litres contains helium gas at standard temperature and pressure. The amount of heat needed to raise the temperature of gas in the cylinder by 20.0°C will be :

(Given gas constant R = $8.3JK^{-1} - mol^{-1}$)
[29-Jun-2022-Shift-1]

Options:

A. 249J

B. 415J

C. 498J

D. 830J

Answer: C

Solution:

Solution:

No of moles $= \frac{44.8}{22.4} = 2$

Gas is mono atomic so $C_v = \frac{3}{2}R$

$\Delta Q = nC_v \Delta T$

$= 2 \times \frac{3}{2}R(20)$

$= 60R$

$= 60 \times 8.3$

$= 498J$

Question100

300 cal. of heat is given to a heat engine and it rejects 225 cal. If source temperature is 227°C, then the temperature of sink will be _____°C.
[29-Jun-2022-Shift-1]

Answer: 102

Solution:

Solution:

$$\eta = \frac{W}{Q} = \frac{300-225}{300}$$

$$\Rightarrow \frac{75}{300} = 1 - \frac{T_L}{T_H}$$

$$\Rightarrow T_L = \frac{3}{4}T_H = \frac{3}{4}(500) = 375K$$

$$\Rightarrow T_L = 102^{\circ}C$$

Question101

Starting with the same initial conditions, an ideal gas expands from volume V_1 to V_2 in three different ways. The work done by the gas is W_1 if the process is purely isothermal, W_2, if the process is purely adiabatic and W_3 if the process is purely isobaric. Then, choose the correct option
[29-Jun-2022-Shift-2]

Options:

A. $W_1 < W_2 < W_3$

B. $W_2 < W_3 < W_1$

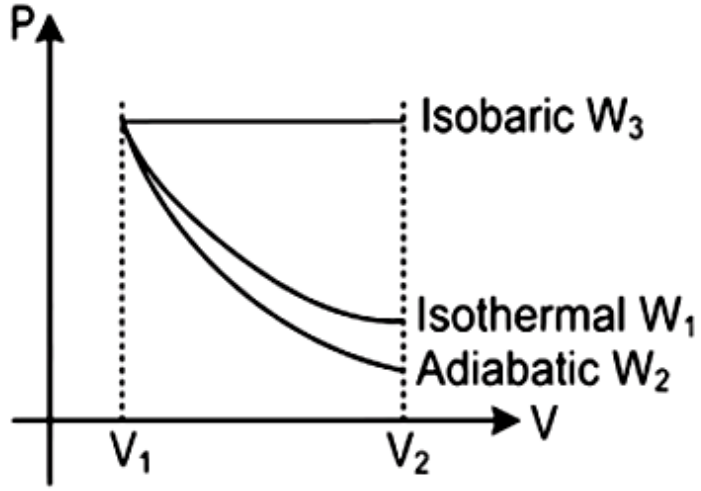
C. $W_3 < W_1 < W_2$

D. $W_2 < W_1 < W_3$

Answer: D

Solution:

Solution:



Comparing the area under the PV graph$A_3 > A_1 > A_2$
$\Rightarrow W_3 > W_1 > W_2$

Question102

A certain amount of gas of volume V at 27°C temperature and pressure $2 \times 10^7 \text{N m}^{-2}$ expands isothermally until its volume gets doubled. Later it expands adiabatically until its volume gets redoubled. The final pressure of the gas will be (Use $\gamma = 1.5$) : [25-Jul-2022-Shift-1]

Options:

A. $3.536 \times 10^5 \text{Pa}$

B. $3.536 \times 10^6 \text{Pa}$

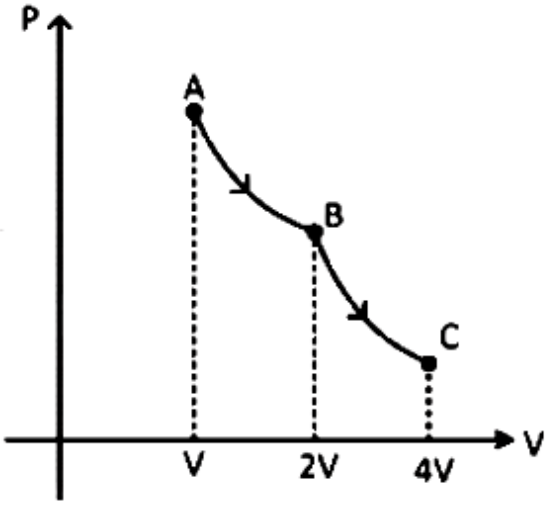
C. $1.25 \times 10^6 \text{Pa}$

D. $1.25 \times 10^5 \text{Pa}$

Answer: B

Solution:

Solution:



Let AB is isothermal process and BC is adiabatic process then for AB process

$P_A V_A = P_B V_B$

$\Rightarrow P_B = 10^7 \text{N m}^{-2}$

For process BC

$P_B V_B^r = P_C V_C^r$

$P_C = 3.536 \times \times 10^6 \text{Pa}$

Question103

Let η_1 is the efficiency of an engine at $T_1 = 447^\circ C$ and $T_2 = 147^\circ C$ while η_2 is the efficiency at $T_1 = 947^\circ C$ and $T_2 = 47^\circ C$ The ratio $\frac{\eta_1}{\eta_2}$ will be:
[25-Jul-2022-Shift-2]

Options:

A. 0.41

B. 0.56

C. 0.73

D. 0.70

Answer: B

Solution:

Solution:

$\eta_1 = 1 - \frac{420}{720} = \frac{300}{720}$

And $\eta_2 = 1 - \frac{320}{1220} = \frac{900}{1220}$

$\Rightarrow \frac{\eta_1}{\eta_2} = \frac{300}{720} \times \frac{1220}{900}$

$\simeq 0.56$

Question104

7 mol of a certain monoatomic ideal gas undergoes a temperature increase of 40K at constant pressure. The increase in the internal energy of the gas in this process is : (Given R = $8.3JK^{-1}mol^{-1}$) [26-Jul-2022-Shift-1]

Options:

A. 5810J

B. 3486J

C. 11620J

D. 6972J

Answer: B

Solution:

Solution:

$\Delta U = nC_v \Delta T$

$= 7 \times \frac{3R}{2} \times 40$

$= 3486J$

Question105

A monoatomic gas at pressure P and volume V is suddenly compressed to one eighth of its original volume. The final pressure at constant entropy will be : [26-Jul-2022-Shift-1]

Options:

A. P

B. 8P

C. 32P

D. 64P

Answer: C

Solution:

Solution:

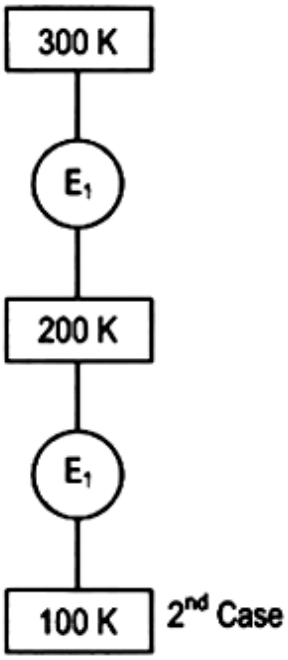
$PV^{\gamma} =$ constant

$\Rightarrow PV^{\gamma} = (P')\left(\frac{v}{8}\right)^{\gamma}$ where $\gamma = 5/3$

$\Rightarrow P' = 32P$

Question106

In 1 st case, Carnot engine operates between temperatures 300K and 100K . ln 2 nd case, as shown in the figure, a combination of two engines is used. The efficiency of this combination (in 2 nd case) will be :



[27-Jul-2022-Shift-2]

Options:

A. same as the 1 st case.

B. always greater than the 1 st case.

C. always less than the 1 st case.

D. may increase or decrease with respect to the 1 st case.

Answer: A

Solution:

Solution:

First case : $\eta = 1 - \frac{100}{300} = \frac{2}{3}$

Second case : $\eta_{net} = \eta_1 + \eta_2 - \eta_1\eta_2$

$\eta_1 = 1 - \frac{200}{300} = \frac{1}{3}$

$\eta_2 = 1 - \frac{100}{200} = \frac{1}{2}$

$\eta_{net} = \frac{1}{3} + \frac{1}{2} - \frac{1}{6} = \frac{2}{3}$

η(first case) = η(second case)

Question107

A Carnot engine has efficiency of 50%. If the temperature of sink is reduced by 400°C, its efficiency increase by 30%. The temperature of the source will be:
[28-Jul-2022-Shift-1]

Options:

A. 166.7K

B. 255.1K

C. 266.7K

D. 367.7K

Answer: C

Solution:

Solution:

$$\eta = 1 - \frac{T_L}{T_H}$$

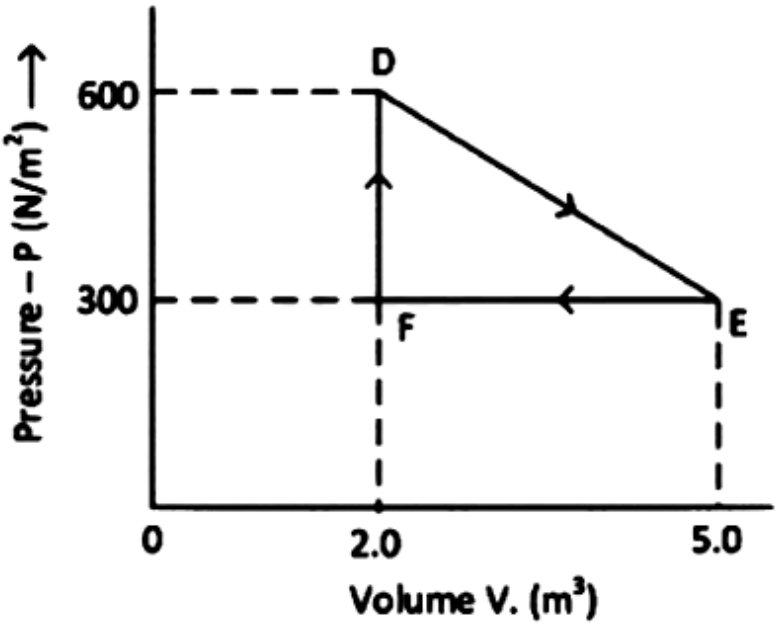
$$\frac{1}{2} = 1 - \frac{T_L}{T_H}$$

$$\frac{1}{2}(1 \cdot 3) = 1 - \left(\frac{T_L - 40}{T_H} \right)$$

$$\frac{1}{2}(1 \cdot 3) = \frac{1}{2} + \frac{40}{T_H} \quad T_H = 266.7\text{K}$$

Question108

A thermodynamic system is taken from an original state D to an intermediate state E by the linear process shown in the figure. Its volume is then reduced to the original volume from E to F by an isobaric process. The total work done by the gas from D to E to F will be



[29-Jul-2022-Shift-2]

Options:

A. −450J

B. 450J

C. 900J

D. 1350J

Answer: B

Solution:

Solution:

$W_{DE} = \frac{1}{2}(600 + 300)3J$

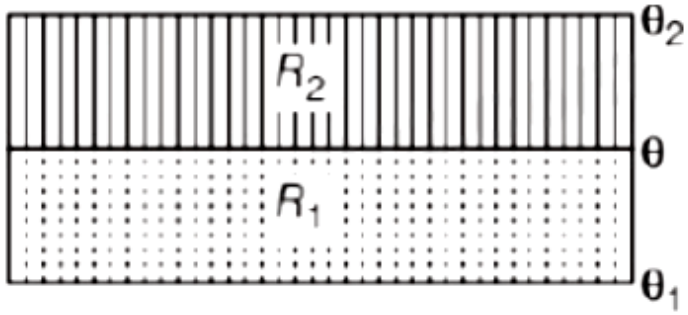
$= 1350J$

$W_{EF} = -300 \times 3 = -900J$

$W_{DEF} = 450J$

Question109

The temperature θ at the junction of two insulating sheets, having thermal resistances R_1 and R_2 as well as top and bottom temperatures θ_1 and θ_2 (as shown in figure) is given by



[26 Feb 2021 Shift 1]

Options:

A. $\frac{\theta_2 R_2 - \theta_1 R_1}{R_2 - R_1}$

B. $\frac{\theta_1 R_2 - \theta_2 R_1}{R_2 - R_1}$

C. $\frac{\theta_1 R_2 + \theta_2 R_1}{R_1 + R_2}$

D. $\frac{\theta_1 R_1 + \theta_2 R_2}{R_1 + R_2}$

Answer: C

Solution:

Solution:
Let, $Q =$ heat current,
$k =$ thermal conductivity,
A = area,
$I =$ length of capacitor
and $\Delta\theta =$ change in temperature .

$$\therefore \ Q = \frac{kA\,\Delta\theta}{l} = \frac{\Delta\theta}{R} \quad \left(\because R = \frac{l}{kA}\right)$$

$$\Rightarrow \quad \frac{\theta_2 - \theta}{R_2} = \frac{\theta - \theta_1}{R_1}$$

$$\Rightarrow R_1\theta_2 - R_1\theta = R_2\theta - R_2\theta_1$$

$$\Rightarrow \theta = \frac{R_1\theta_2 + R_2\theta_1}{R_1 + R_2}$$

Question110

A reversible heat engine converts one-fourth of the heat input into work. When the temperature of the sink is reduced by 52K , its efficiency is doubled. The temperature in kelvin of the source will be ..... .
[25 Feb 2021 Shift 2]

Answer: 104

Solution:

Solution:
Given, initial efficiency $(\eta_h) = 1/4$

$$\Rightarrow \ \eta_h = 1 - \frac{T_2}{T_1} = \frac{1}{4} \Rightarrow \frac{T_2}{T_1} = 1 - \frac{1}{4} = \frac{3}{4}$$

When temperature of sink is reduced by $50K$,

$$\eta_2 = 2\eta_1 = 1 - \frac{T_2 - 52}{T_1}$$

$$\Rightarrow 2 \times \frac{1}{4} = 1 - \frac{T_2}{T_1} + \frac{52}{T_1}$$

$$\Rightarrow \ \frac{1}{2} = 1 - \frac{3}{4} + \frac{52}{T_1} \Rightarrow \frac{1}{2} - \frac{1}{4} = \frac{52}{T_1}$$

$\Rightarrow \frac{2}{4} = \frac{52}{T_1}$

$\Rightarrow T_1 = 104K$

Question111

1 mole of rigid diatomic gas performs a work of Q/5 when heat Q is supplied to it. The molar heat capacity of the gas during this transformation is $\frac{xR}{8}$, The value of x is ..... .

[R = universal gas constant]
[26 Feb 2021 Shift 2]

Answer: 25

Solution:

Solution:
Given, number of mole, $n = 1$
Heat supplied $= Q$
Work done $= Q/5$
By using first law of thermodynamics,
$\Delta Q = \Delta U + \Delta W$
$Q = \Delta U + Q/5$
$\Delta U = 4Q/5 = nC_v \Delta T$ . . . (i)
where, C_V is heat coefficient at constant volume and
ΔT is change in temperature.
Degree of freedom of diatomic gas, $f = 5$
$\therefore Q = \frac{5}{4}\frac{f}{2}R\Delta T$ [from Eq. (i)] $\Rightarrow \frac{Q}{\Delta T} = C = \frac{5}{4}\times\frac{5}{2}R = \frac{25}{8}R$
Hence, $x = 25$

Question112

Match List-I with List-II:

List-I	List-II
(A) Isothermal	(i) Pressure constant
(B) Isochoric	(ii) Temperatureconstant
(C) Adiabatic	(iii) Volume constant
(D) Isobaric	(iv) Heat content isconstant

Choose the correct answer from the options given below: [24feb2021shift1]

Options:

A. (A) rightarrow (i), (B) rightarrow (iii), (C) rightarrow (ii), (D) rightarrow (iv)

B. (A) rightarrow (ii), (B) rightarrow (iii), (C) rightarrow (iv), (D) rightarrow (i)

C. (A) rightarrow (ii), (B) rightarrow (iv), (C) rightarrow (iii), (D) rightarrow (i)

D. (A) rightarrow (iii), (B) rightarrow (ii), (D) rightarrow (i), (D) rightarrow (iv)

Answer: B

Solution:

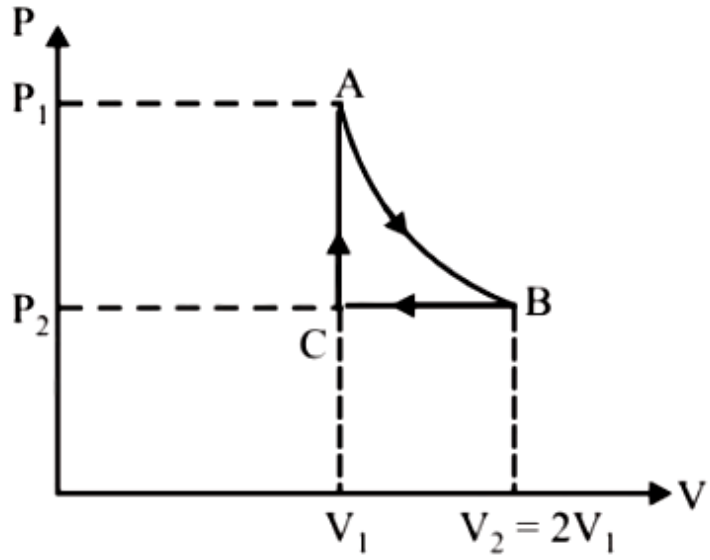
Solution:
(A) Isothermal ($\Delta T = 0$) (A) $\rightarrow$ (ii)
(B) Isochoric ($\Delta V = 0$) (B) $\rightarrow$ (iii)
(C) Adiabatic ($\Delta Q = 0$) (C) $\rightarrow$ (iv)
(D) Isobaric ($\Delta P = 0$) (D) $\rightarrow$ (i)

Question113

n mole a perfect gas undergoes a cyclic process ABCA (see (figure) consisting of the following processes.
A $\rightarrow$ B : Isothermal expansion at temperature T so that the volume is doubled from V_1 to $V_2 = 2V_1$ and pressure changes from P_1 to P_2.
B $\rightarrow$ C : Isobaric compression at pressure P_2 to initial volume V_1.

C → A : Isochoric change leading to change of pressure from P_2 to P_1.

Total work done in the complete cycle ABCA is:



[24feb2021shift1]

Options:

A. 0

B. $nRT\left(\ln 2 + \frac{1}{2}\right)$

C. $nRT\ \ln 2$

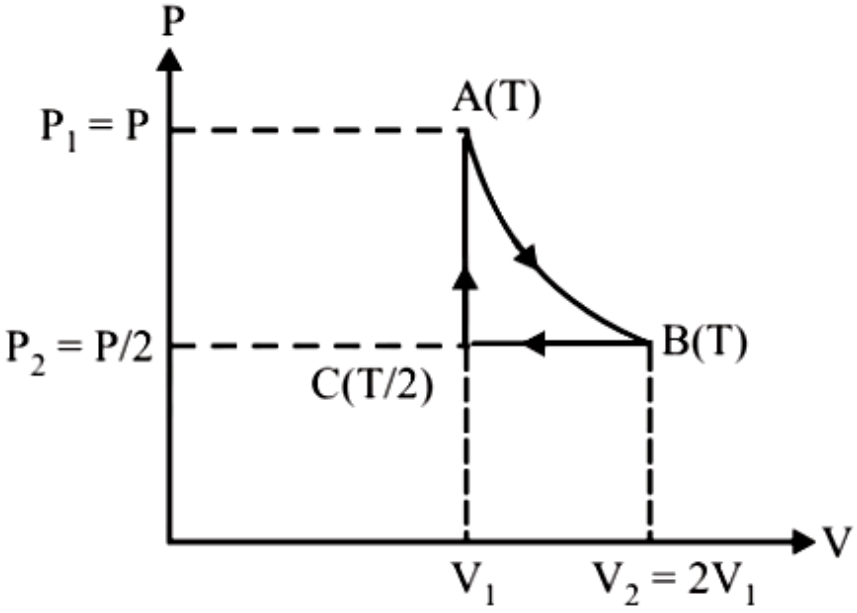
D. $nRT\left(\ln 2 - \frac{1}{2}\right)$

Answer: D

Solution:

Solution:

Work done during isothermal process,



$$W_{AB} = nRT \ln\left(\frac{V_2}{V_1}\right)$$

$$W_{AB} = nRT \ln\left(\frac{2V}{V}\right) = nRT \ln 2$$

$$W_{BC} = nR(T_C - T_B) = nR\left(\frac{T}{2} - T\right) = -nR\frac{T}{2}$$

$$W_{CA} = P\Delta V = 0 \quad (\because \Delta V = 0)$$

$$\Rightarrow W_{net} = W_{AB} + W_{BC} + W_{CA}$$

$$\Rightarrow W_{net} = nRT \ln 2 - \frac{nRT}{2}$$

$$\Rightarrow W_{net} = nRT\left(\ln 2 - \frac{1}{2}\right)$$

Question114

The volume V of a given mass of monoatomic gas changes with temperature T according to the relation $V = kT^{2/3}$. The work done when temperature changes by 90K will be xR. The value of x is..... [R = universal gas constant]
[26 Feb 2021 Shift 2]

Answer: 60

Solution:

Solution:

Given, $V = kT^{2/3}$ ... (i)

where, T is temperature.

Change in temperature, $\Delta T = 90K$

Let p be the pressure, dV be the change in volume and work done be W.

As we know that,

$W = \int p dV$ ... (ii)

As, $pV = nRT$

$\therefore p = \frac{nRT}{V}$

Substituting this value in Eq. (ii), we get

$W = \int nRT \frac{dV}{V}$

$W = \int nRT \frac{dV}{kT^{2/3}}$ [using Eq. (i)] ... (iii)

On differentiating Eq. (i) w.r.t. temperature on both sides, we get

$\frac{dV}{dT} = k \cdot \frac{2}{3} T^{1/3}$

$= \frac{2}{3} kT^{-1/3} = \frac{2}{3} \frac{k}{T^{1/3}}$

$\therefore dV = 2/3kT^{-1/3} dT$

Substituting this in Eq. (iii), we get

$W = \int nRT \frac{2/3kT^{-1/3} dT}{kT^{2/3}}$

$\Rightarrow W = \frac{2}{3} nR \int T dT = 2/3nR[T]_{T_1}^{T}$

$= 2/3nR[T_2 - T_1] = 2/3nR \Delta T$

$= 2/3nR90 = 60nR$

Here, $n = 1$

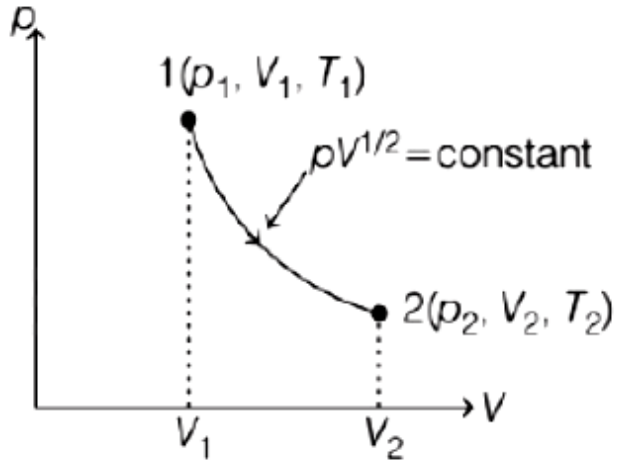
So, work done will be $60R$.

Hence, $x = 60$.

Question115

Thermodynamic process is shown below on a p-V diagram for one mole of an ideal gas.

If $V_2 = 2V_1$, then the ratio of temperature $\frac{T_2}{T_1}$ is



[25 Feb 2021 Shift 2]

Options:

A. $\frac{1}{\sqrt{2}}$

B. $\sqrt{2}$

C. $\frac{1}{2}$

D. 2

Answer: B

Solution:

Solution:
Here, p_1 and p_2, T_1 and T_2, V_1 and V_2 are initial and final pressures, temperatures and volumes, respectively.
Given, $V_2 = 2V_1$
$pV^{1/2} =$ constant
From graph, $\gamma =$ adiabatic constant $= 1/2$

$$\Rightarrow p_1 V_1^{1/2} = p_2 V_2^{1/2} \Rightarrow \frac{p_1}{p_2} = \left(\frac{2V_1}{V_1}\right)^{1/2} = 2^{1/2}$$

Also, $p^{1-\gamma} T^{\gamma} =$ constant (for adiabatic process)

$$\Rightarrow p_1^{1-\gamma} T_1^{\gamma} = p_2^{1-\gamma} T_2^{\gamma}$$

$$\Rightarrow \left(\frac{p_1}{p_2}\right)^{1-\gamma} = \left(\frac{T_2}{T_1}\right)^{\gamma} \Rightarrow \left(\frac{p_1}{p_2}\right)^{\frac{1-\gamma}{\gamma}} = \frac{T_2}{T_1}$$

$$\therefore T_2/T_1 = (2^{1/2})^{\frac{1-0.5}{0.5}} = \sqrt{2}$$

Question116

In a certain thermodynamical process, the pressure of a gas depends on its volume as kV^3. The work done when the temperature changes from 100°C to 300°C will be ..... nR, where n denotes number of moles of a gas.
[25 Feb 2021 Shift 1]

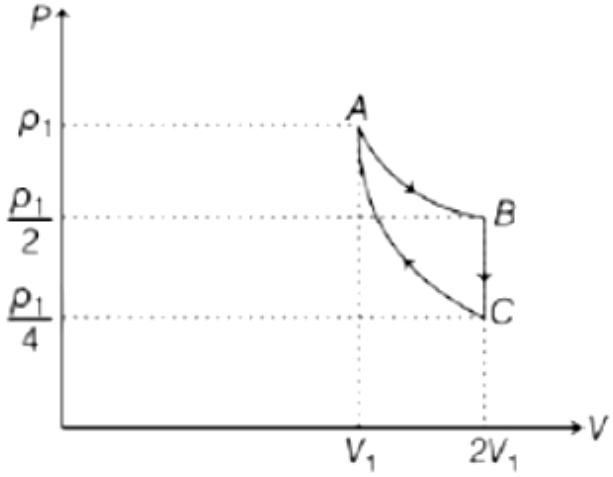
Answer: 50

Solution:

Solution:
Given, pressure $(p) \propto kV^3$
$T_1 = 100^\circ C, T_2 = 300^\circ C$
$\Delta T = T_2 - T_1 = 300 - 100 = 200^\circ C$
$\Rightarrow$ By using ideal gas equation,
$pV = nRT$
$kV^3 \cdot V = nRT \Rightarrow kV^4 = nRT$
On differentiating both sides w.r.t temperature, we get
$4kV^3 \frac{dV}{dT} = nR$
$\Rightarrow 4kV^3 dV = nRdT \Rightarrow kV^3 dV = nRdT/4$
$\Rightarrow pdV = nRdT/4$
As, work done $(W) = pdV = nRdT/4$
$= \frac{nR}{4}\Delta T = \frac{nR}{4} \times 200 = 50nR$

Question117

If one mole of an ideal gas at (p_1, V_1) is allowed to expand reversibly and isothermally (A to B), its pressure is reduced to one-half of the original pressure (see figure). This is followed by a constant volume cooling till its pressure is reduced to one-fourth of the initial value (B → C). Then, it is restored to its initial state by a reversible adiabatic compression (C to A). The net work done by the gas is equal to



[24 Feb 2021 Shift 2]

Options:

A. $RT\left(\ln 2 - \frac{1}{2(\gamma-1)}\right)$

B. $-\frac{RT}{2(\gamma-1)}$

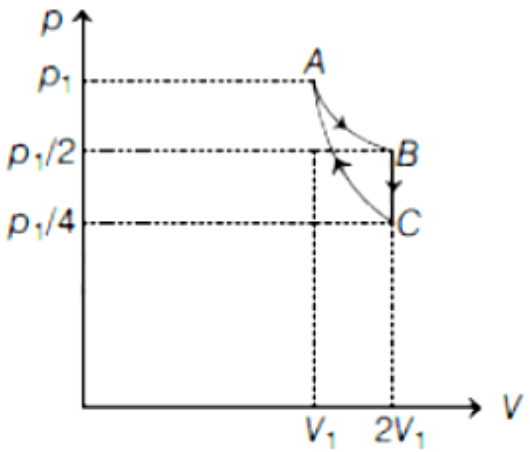
C. 0

D. $RT\ln 2$

Answer: A

Solution:

Solution:
Let p_i, p_f, V_i and V_f be the initial and final pressure and volume.
Given, AB is isothermal ($\Delta T = 0$),
BC is isochoric ($\Delta V = 0$)
and CA is adiabatic ($\Delta Q = 0$)
Since, isothermal work $(W_{AB}) = p_1 V_1 \ln \frac{V_f}{V_i}$



where, V_i and V_f are volume at A and B, respectively.

$\therefore\ W_{AB} = p_1 V_1 \ln \frac{2V_1}{V_1} = p_1 V_1 \ln 2$

Since, at constant volume, work done is zero.

$\therefore\ W_{BC} = 0$

Since, W_{CA} is an adiabatic work done,

i.e. $W_{CA} = \frac{1}{1-\gamma}(p_f V_f - p_i V_i)$

$\Rightarrow\ W_{CA} = \frac{1}{1-\gamma}\left(p_1 V_1 - \frac{p_1}{4} \times 2V_1\right)$

$= \frac{1}{1-\gamma}(p_1 V_1 - p_1 V_1/2) = \frac{1}{1-\gamma}\frac{p_1 V_1}{2}$

$\therefore$ Net work done, $W_{net} = W_{AB} + W_{BC} + W_{CA}$

$= p_1 V_1 \ln 2 + 0 + \frac{1}{1-\gamma}\frac{p_1 V_1}{2}$

$= p_1 V_1 [\ln 2 + 1/2(1-\gamma)]$

From ideal gas law, $pV = nRT$

$\therefore W_{net} = RT\,[\ln 2 - 1/2(\gamma - 1)]$

$(\because n = 1)$

Question118

In thermodynamics, heat and work are [16 Mar 2021 Shift 1]

Options:

A. path functions

B. intensive thermodynamic state variables

C. extensive thermodynamic state variables

D. point functions

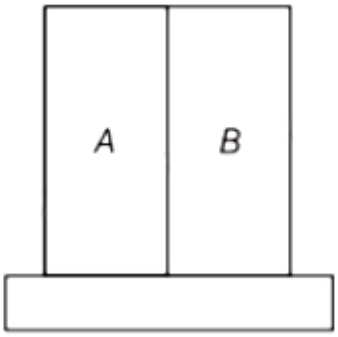
Answer: A

Solution:

Solution:
According to first law of thermodynamics
dQ = dU + dW.....(i)
As we know that, work done by the gas depends on the type of process, i.e. path and dU depends on the initial and final states. So, considering Eq. (i), dQ will also be dependent on path. It means that, in thermodynamics, heat and work are path functions.

Question119

A bimetallic strip consists of metals A and B. It is mounted rigidly as shown. The metal A has higher coefficient of expansion compared to that of metal B. When the bimetallic strip is placed in a cold bath, it will



[16 Mar 2021 Shift 2]

Options:

A. bend towards the right

B. not bend but shrink

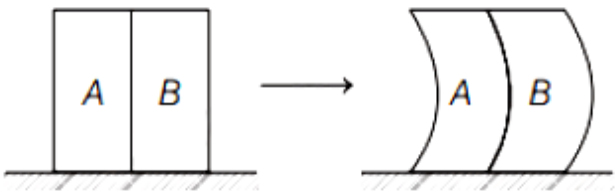
C. Neither bend nor shrink

D. bend towards the left

Answer: D

Solution:

Solution:
As per the question, coefficient of expansion of metal A is higher than that of B.
It means, $\alpha_A > \alpha_B$
If the bimetallic strip is placed in a cold bath, then the length of both strips will decrease.
i.e., $I_A > I_B$
∴ The bimetallic strip will bend towards left.
It can be shown as below.



Question120

Two identical metal wires of thermal conductivities K_1 and K_2 respectively are connected in series. The effective thermal conductivity of the combination is
[17 Mar 2021 Shift 1]

Options:

A. $\frac{2K_1K_2}{K_1+K_2}$

B. $\frac{K_1+K_2}{2K_1K_2}$

C. $\frac{K_1+K_2}{K_1K_2}$

D. $\frac{K_1K_2}{K_1+K_2}$

Answer: A

Solution:

Solution:
Two identical metal wires of thermal conductivities K_1 and K_2 respectively connected in series are represented as follows

The above figure can also be represented as

Therefore, the effective thermal conductivity of the combination will be given by

$$R_{eff} = \frac{I}{K_1A} + \frac{I}{K_2A} = \frac{2l}{K_{eq}A}$$

$$\Rightarrow \frac{2I}{K_{eq}A} = \frac{1}{A}\left(\frac{1}{K_1} + \frac{1}{K_2}\right) \Rightarrow \frac{2I}{K_{eq}A} = \frac{I}{A}\left(\frac{K_1+K_2}{K_1K_2}\right)$$

$$\Rightarrow \frac{2}{K_{eq}} = \frac{K_1+K_2}{K_1K_2} \Rightarrow K_{eq} = \frac{2K_1K_2}{K_1+K_2}$$

Question121

An ideal gas in a cylinder is separated by a piston in such a way that the entropy of one part is S_1 and that of the other part is S_2. Given

that $S_1 > S_2$. If the piston is removed, then the total entropy of the system will be
[18 Mar 2021 Shift 2]

Options:

A. $S_1 \times S_2$

B. $S_1 - S_2$

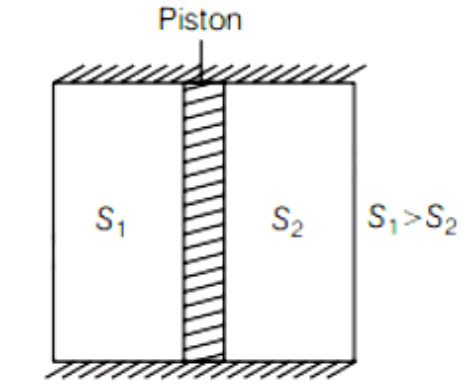
C. $\frac{S_1}{S_2}$

D. $S_1 + S_2$

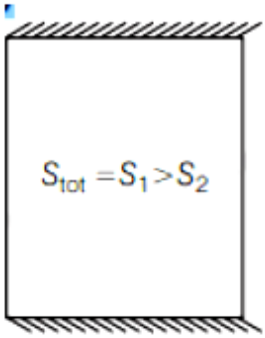
Answer: D

Solution:

Solution:
Entropy present in one part of the system is S_1.
Entropy present in other part of the system is S_2.



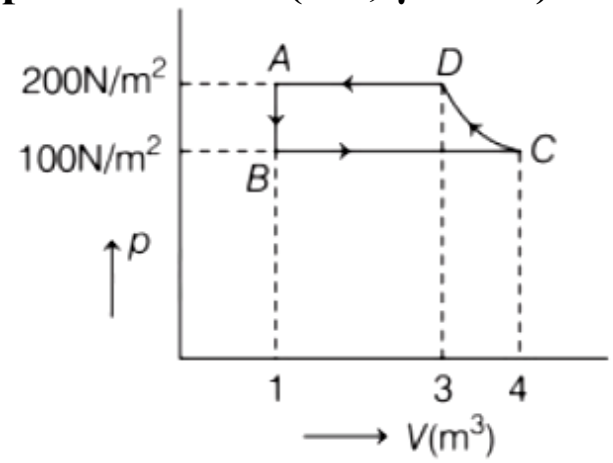
After removing piston,



After removing piston,
We know that,
$\Delta S_{unvi} = \Delta S_{sys} + \Delta S_{surr}$
Thus, after removing the piston, the total entropy present in system,
$S_{tot} = S_1 + S_2$

Question122

The p − V diagram of a diatomic ideal gas system going under cyclic process as shown in figure. The work done during an adiabatic process CD is (use, γ = 1.4)



[18 Mar 2021 Shift 1]

Options:

A. −500J

B. −400J

C. 400J

D. 200J

Answer: A

Solution:

Solution:
Given
The final pressure of the adiabatic process, $p_f = 200\text{N}/\text{m}^2$
The initial pressure of the adiabatic process, $p_i = 100\text{N}/\text{m}^2$
The initial volume of the adiabatic process, $V_1 = 4\text{m}^3$
The final volume of the adiabatic process, $V_f = 3\text{m}^3$
We know that, for an adiabatic process

$$W = \frac{p_f V_f - p_i V_i}{1-\gamma}$$

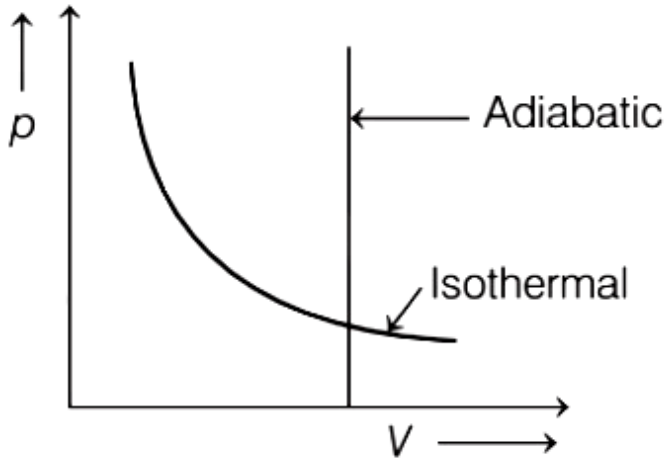
$$\Rightarrow W = \frac{200(3)-(100)(4)}{1-1.4}$$

$$\Rightarrow W = -500\text{J}$$

So, the work done by an adiabatic process is $500J$ and negative sign represents the work done on the system.

Question123

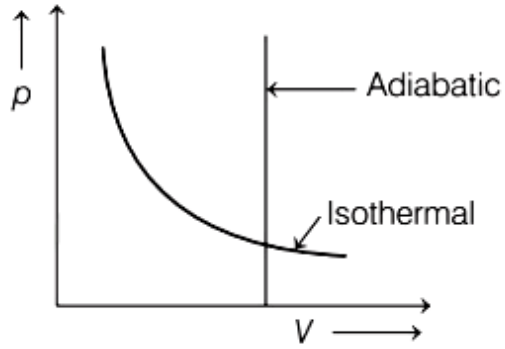
Which one is the correct option for the two different thermodynamic processes?



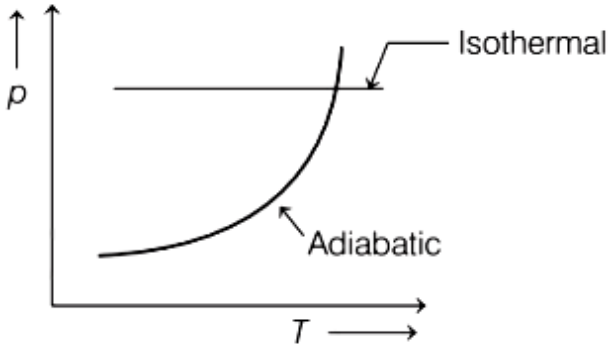
[17 Mar 2021 Shift 2]

Options:

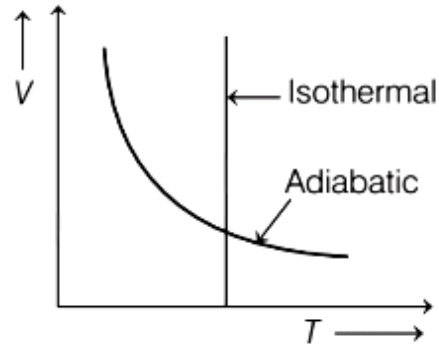
A.



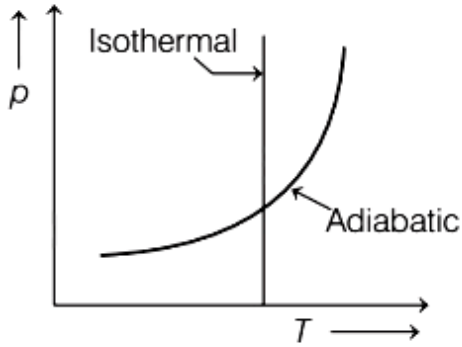
B.



C.



D.



Answer: B

Solution:

Solution:
In graph (A) vertical line is isochoric process, so the graph (A) is incorrect.
In graph (B) horizontal line is isobaric process, so the graph (B) is incorrect.
In graph (C) and (D) vertical line is isothermal process and the curve line is adiabatic process.
So, the correct representation of thermodynamic process graph is (C) and (D).
So, the correct option is (b)

Question124

A Carnot's engine working between 400K and 800K has a work output of 1200J per cycle. The amount of heat energy supplied to the engine from the source in each cycle is
[17 Mar 2021 Shift 1]

Options:

A. 3200J

B. 1800J

C. 1600J

D. 2400J

Answer: D

Solution:

Solution:
Efficiency of Carnot heat engine is given by

$$\eta = 1 - \frac{T_2}{T_1}$$

$$= 1 - \frac{Q_2}{Q_1} = \frac{W}{Q_1} \text{.....(i)}$$

where. W = net work done by the gas
Q_1 = heat absorbed by the gas,
Q_2 = heat released by the gas,
T_1 = temperature of hot reservoir,
and T_2 = temperature of cold reservoir.
Using Eq. (i), we can write

$$1 - \frac{T_2}{T_1} = \frac{W}{Q_1} \Rightarrow \frac{T_2}{T_1} = 1 - \frac{W}{Q_1}$$

$$\Rightarrow \frac{400}{800} = 1 - \frac{W}{Q_1} \Rightarrow \frac{W}{Q_1} = 1 - \frac{400}{800}$$

$$\Rightarrow \frac{W}{Q_1} = 1 - \frac{1}{2} = \frac{1}{2} \Rightarrow \frac{W}{Q_1} = \frac{1}{2}$$

$$\Rightarrow Q_1 = 2 \times W = 2 \times 1200 [\because W_1 = 1200 J]$$

$$= 2400 J$$

Question125

For an ideal heat engine, the temperature of the source is 127°C. In order to have 60% efficiency the temperature of the sink should be ..... °C.
(Round off to the nearest integer)
[16 Mar 2021 Shift 2]

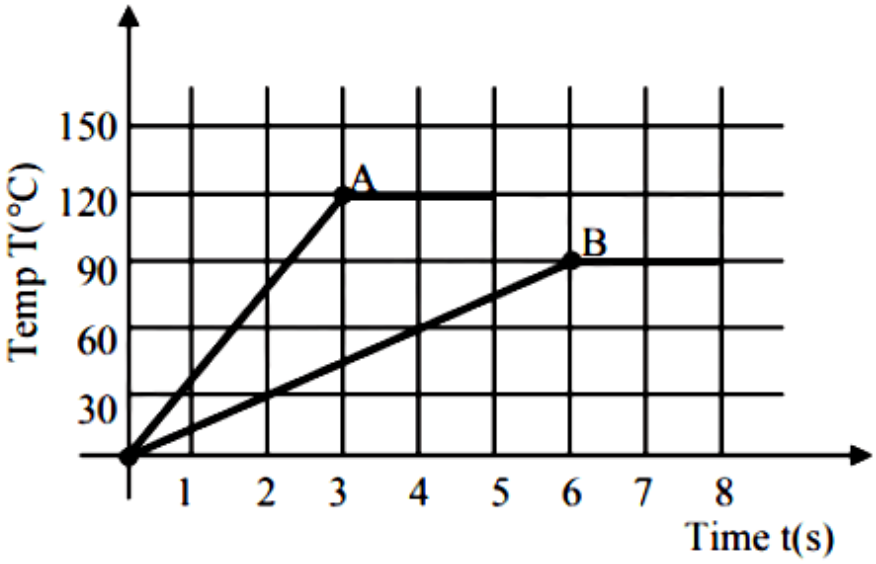
Answer: 113

Solution:

Solution:
Given, temperature of source, $T_H = 127^\circ C$
$= 273 + 127 = 400K$
Efficience, $\eta = 60\% = 0.6$
The efficiency of Carnot (ideal) heat engine is given by
$\eta = \left(1 - \frac{T_L}{T_H}\right)$
where, $T_L =$ temperature of sink,
$0.6 = \left(1 - \frac{T_L}{T_H}\right) \Rightarrow \frac{T_L}{T_H} = 1 - 0.6$
$\frac{T_L}{T_H} = 0.4 \Rightarrow T_L = 0.4 \times T_H$
$= 0.4 \times 400 = 160K$
$= 160 - 273 = -113^\circ C$

Question126

Two different metal bodies A and B of equal mass are heated at a uniform rate under similar conditions. The variation of temperature of the bodies is graphically represented as shown in the figure. The ratio of specific heat capacities is :



[25 Jul 2021 Shift 1]

Options:

A. $\frac{8}{3}$

B. $\frac{3}{8}$

C. $\frac{3}{4}$

D. $\frac{4}{3}$

Answer: B

Solution:

Solution:

$\left(\frac{\Delta Q}{\Delta t}\right)_A = \left(\frac{\Delta Q}{\Delta t}\right)_B$

$mS_A\left(\frac{\Delta T}{\Delta t}\right)_A = mS_B\left(\frac{\Delta T}{\Delta t}\right)_B$

$\frac{S_A}{S_B} = \frac{\left(\frac{\Delta T}{\Delta t}\right)_A}{\left(\frac{\Delta T}{\Delta t}\right)_B} = \frac{90/6}{120/3} = \frac{15}{40} = \frac{3}{8}$

Question127

A body takes 4 min. to cool from 61° C to 59°C. If the temperature of the surroundings is 30°C, the time taken by the body to cool from 51°C to 49° C is :
[27 Jul 2021 Shift 1]

Options:

A. 4 min.

B. 3 min.

C. 8 min.

D. 6 min.

Answer: D

Solution:

Solution:

$\frac{\Delta T}{\Delta t} = K(T_t - T_s)$

$T_t =$ average temp

$T_S =$ surrounding temp.

$\frac{61-59}{4} = K\left(\frac{61+59}{2} - 30\right)$ .....(1)

$\frac{51-49}{t} = K\left(\frac{51+49}{2} - 30\right)$ .....(2)

Divide (1) & (2)

$\frac{t}{4} = \frac{60-30}{50-30} = \frac{30}{20}$

so, $t = 6$ minutes

Question128

In 5 minutes, a body cools from 75°C to 65°C at room temperature of 25°C. The temperature of body at the end of next 5 minutes is _____°C

[22 Jul 2021 Shift 2]

Answer: 57

Solution:

Solution:

By newton's law of cooling (with approximation)

$\frac{\Delta T}{\Delta t} = -C(T_{arg} - T_s)$

$1^{st}\ \frac{-10°C}{5min} = -C(70°C - 25°C)$

$\Rightarrow C = \frac{2}{45}min^{-1}$

$2^{nd}\ \frac{T-65}{5min} = -C\left(\frac{T+65}{2} - 25\right) = -\left(\frac{2}{45}\right)\left(\frac{T+15}{2}\right) \Rightarrow 9(T-65) = -(T+15)$

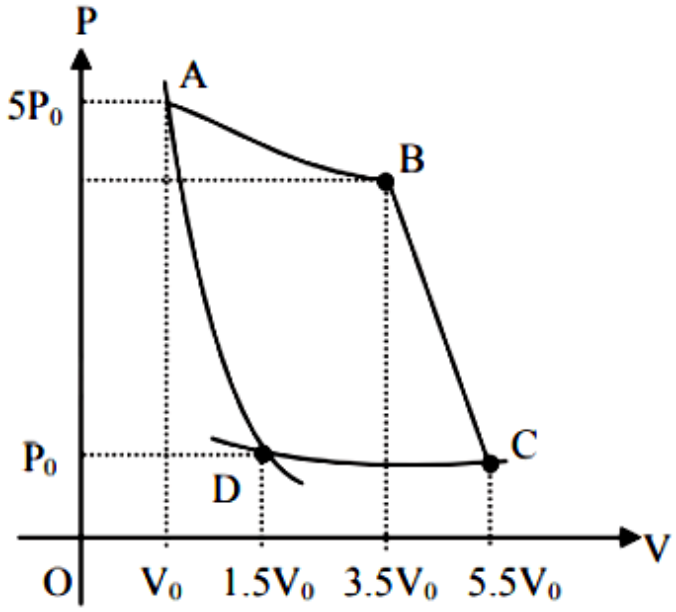
$\Rightarrow 10T = 570$

$\Rightarrow T = 57°C$

Question129

In the reported figure, there is a cyclic process ABCDA on a sample of 1 mol of a diatomic gas. The temperature of the gas during the

process A → B and C → D are T_1 and $T_2 (T_1 > T_2)$ respectively.



Choose the correct option out of the following for work done if processes BC and DA are adiabatic.
[27 Jul 2021 Shift 1]

Options:

A. $W_{AB} = W_{DC}$

B. $W_{AD} = W_{BC}$

C. $W_{BC} + W_{DA} > 0$

D. $W_{AB} < W_{CD}$

Answer: B

Solution:

Solution:

Work done in adiabatic process $= \frac{-nR}{\gamma - 1}(T_f - T_i)$

$\therefore W_{AD} = \frac{-nR}{\gamma - 1}(T_2 - T_1)$

and $W_{BC} = \frac{-nR}{\gamma - 1}(T_2 - T_1)$

$\therefore W_{AD} = W_{BC}$

Question130

A monoatomic ideal gas, initially at temperature T_1 is enclosed in a cylinder fitted with a frictionless piston. The gas is allowed to expand adiabatically to a temperature T_2 by releasing the piston suddenly. If l_1 and l_2 are the lengths of the gas column, before and after the expansion respectively, then the value of $\frac{T_1}{T_2}$ will be :

[25 Jul 2021 Shift 1]

Options:

A. $\left(\frac{l_1}{l_2}\right)^{\frac{2}{3}}$

B. $\left(\frac{l_2}{l_1}\right)^{\frac{2}{3}}$

C. $\frac{l_2}{l_1}$

D. $\frac{l_1}{l_2}$

Answer: B

Solution:

Solution:

$PV^r = \text{const}$

$TV^{r-1} = \text{const.}$

$T(l)^{\frac{5}{3}-1} = \text{const}$

$\frac{T_1}{T_2} = \left(\frac{l_2}{l_1}\right)^{2/3}$

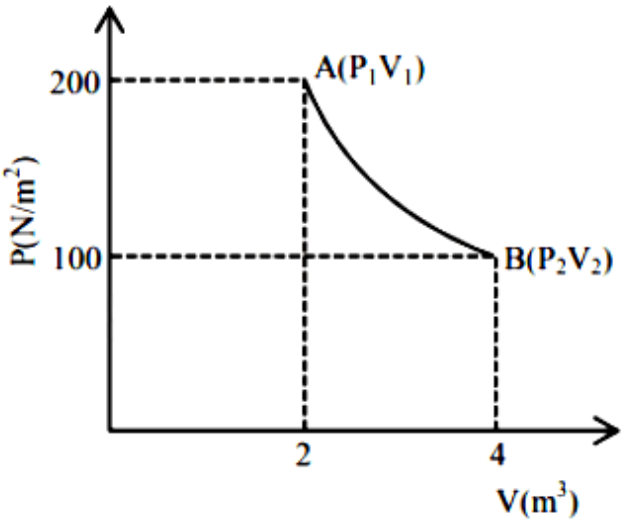
Question131

One mole of an ideal gas at 27°C is taken from A to B as shown in the given PV indicator diagram.

The work done by the system will be _____ $\times 10^{-1}$J .

[Given: R = 8.3J / mol eK , ln 2 = 0.6931]

(Round off to the nearest integer)



[20 Jul 2021 Shift 2]

Answer: 17258

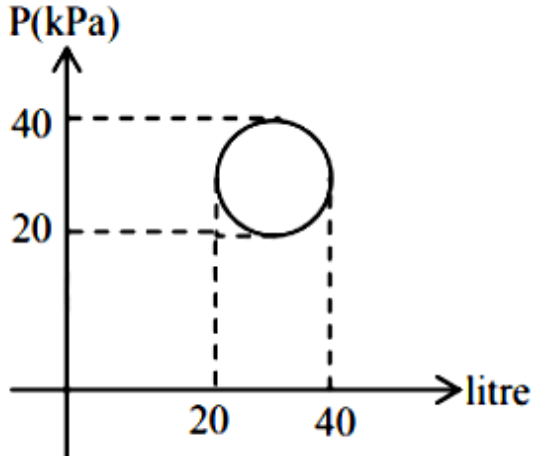
Solution:

Solution:
Process of isothermal

$$W = nRT\ln\left(\frac{V_2}{V_1}\right)$$
$$= 1 \times 8.3 \times 300 \times \ln 2$$
$$= 17258 \times 10^{-1} J$$

Question132

In the reported figure, heat energy absorbed by a system in going through a cyclic process is _____ πJ.



[20 Jul 2021 Shift 1]

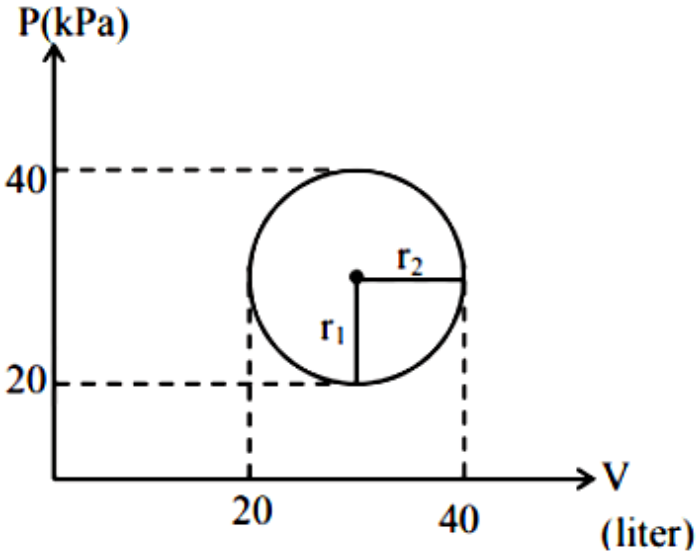
Options:

A.

Answer: 100

Solution:

Solution:



For complete cyclic process

$\Delta U = 0$

$\therefore$ from $\Delta Q = \Delta U + W$

$= 0 + W$

$\Delta Q = W$

= Area

$= \pi r_1 \cdot r_2$

$= \pi \times (10 \times 10^{3}) \times (10 \times 10^{-3})$

$\Delta Q = 100\pi$

Question133

The amount of heat needed to raise the temperature of 4 moles of a rigid diatomic gas from 0°C to 50°C when no work is done is _____. (R is the universal gas constant)
[20 Jul 2021 Shift 1]

Options:

A. 250 R

B. 750 R

C. 175 R

D. 500 R

Answer: D

Solution:

Solution:
$\Delta Q = \Delta U + \Delta W$
Here $\Delta W = 0$
$\Delta Q = \Delta U = nC_V \Delta T$
$\Delta Q = 4 \times \frac{5R}{2}(50) = 500R$
Hence option (4).

Question134

Two Carnot engines A and B operate in series such that engine A absorbs heat at T_1 and rejects heat to a sink at temperature T. Engine B absorbs half of the heat rejected by Engine A and rejects heat to the sink at T_3. When work done in both the cases is equal, to value of T is :
[27 Jul 2021 Shift 2]

Options:

A. $\frac{2}{3}T_1 + \frac{3}{2}T_3$

B. $\frac{1}{3}T_1 + \frac{2}{3}T_3$

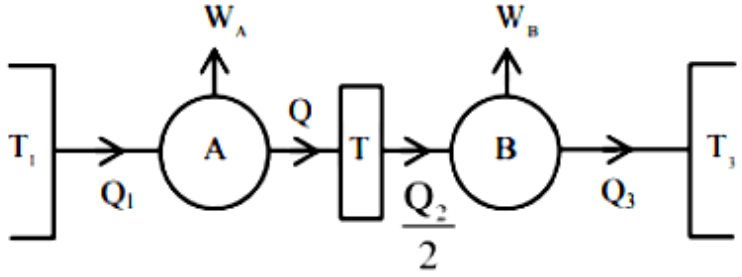
C. $\frac{3}{2}T_1 + \frac{1}{3}T_3$

D. $\frac{2}{3}T_1 + \frac{1}{3}T_3$

Answer: D

Solution:

Solution:



$$W_A = 1 - \frac{Q_2}{Q_1} = 1 - \frac{T}{T_1} \Rightarrow \frac{Q_2}{Q_1} = \frac{T}{T_1}$$

$$W_B = 1 - \frac{Q_3}{(Q_2/2)} = 1 - \frac{T_3}{T} \Rightarrow \frac{2Q_3}{Q_2} = \frac{T_3}{T}$$

Now, $W_A = W_B$

$$Q_1 - Q_2 = \frac{Q_2}{2} - Q_3$$

$$\Rightarrow \frac{2Q_1}{Q_2} + \frac{2Q_3}{Q_2} = 3$$

$$\Rightarrow \frac{2T_1}{T} + \frac{T_3}{T} = 3$$

$$\frac{2T_1}{3} + \frac{T_3}{3} = T$$

Question135

A heat engine has an efficiency of $\frac{1}{6}$. When the temperature of sink is reduced by 62°C, its efficiency get doubled. The temperature of the source is :
[25 Jul 2021 Shift 2]

Options:

A. 124°C

B. 37°C

C. 62°C

D. 99°C

Answer: D

Solution:

Solution:

$\eta = 1 - \frac{T_L}{T_H}$..... (i)

$2\eta = 1 - \frac{(T_L - 62)}{T_H} = 1 - \frac{T_L}{T_H} + \frac{62}{T_H}$

$\Rightarrow \eta = \frac{62}{T_H} \Rightarrow \frac{1}{6} = \frac{62}{T_H} \Rightarrow T_H = 6 \times 62 = 372K$

In°C $\Rightarrow 372 - 273 = 99°C$

Question136

The height of victoria falls is 63m. What is the difference in temperature of water at the top and at the bottom of fall ? [Given, 1 cal = 4.2J and specific heat of water $= 1\,cal\,g^{-1°}\,C^{-1}$] [27 Aug 2021 Shift 2]

Options:

A. 0.147°C

B. 14.76°C

C. 1.476°C

D. 0.014°C

Answer: A

Solution:

Solution:
Given, height of fall, $H = 63m$
Acceleration due to gravity, $g = 9.8ms^{-2}$
Specific heat of water, $s = 1cal\,g^{-1}C^{-1}$
$= 4.2 \times 10^3 J\,kg^{-1}C^{-1}$
Since, energy, $E = mgH = ms\,\Delta T$
where, $m =$ mass

and ΔT = change in temperature.

$\therefore \Delta T = \frac{gH}{s} = \frac{9.8 \times 63}{4.2 \times 10^3} = 0.147^{\circ}C$

Question137

The temperature of equal masses of three different liquids x, y and z are 10°C, 20°C and 30°C, respectively. The temperature of mixture when x is mixed with y is 16°C and that when y is mixed with z is 26°C. The temperature of mixture when x and z are mixed will be [26 Aug 2021 Shift 2]

Options:

A. 28.32°C

B. 25.62°C

C. 23.84°C

D. 20.28°C

Answer: C

Solution:

Solution:
Given masses of three liquids are equal,
i.e. $m_x = m_y = m_z = m$
Temperature of mixture of liquids x and y, $T_1 = 16°C$
Temperature of mixture of liquids y and z, $T_2 = 26°C$
While mixing the liquids x and y, the heat energy lost by liquid y will be equal to the heat energy absorbed by liquid x.
Consider the specific heat capacity of liquid x is s_x, of liquid y is s_y and of liquid z is s_z.
Now, for liquid x and y, using principle of calorimetry,
Heat gained by liquid x = Heat lost by liquid y
$ms_x(T_1 - 10) = ms_y(20 - T_1)$
$\Rightarrow s_x(16 - 10) = s_y(20 - 16)$
$\Rightarrow \frac{s_x}{s_y} = \frac{2}{3}$ ...(i)
Similarly, for liquid y and z, using principle of calorimetry,
Heat gained by liquid y = Heat lost by liquid z
$ms_y(T_2 - 20) = ms_z(30 - T_2)$
$\Rightarrow s_y(26 - 20) = s_z(30 - 26)$ ...(ii)

$\Rightarrow \frac{s_y}{s_z} = \frac{2}{3}$...(i)

Multiply Eq. (i) by Eq. (ii), we get

$\frac{s_x}{s_z} = \frac{4}{9}$

Consider the mixing of liquids x and z, let the temperature of mixture be T_3.

Using principle of calorimetry for liquids x and z.

Heat gained by liquid x = Heat lost by liquid z

$ms_x(T_3 - 10) = ms_z(30 - T_3)$

$\Rightarrow s_x(T_3 - 10) = s_z(30 - T_3)$

$\Rightarrow \frac{s_x}{s_z} = \frac{30 - T_3}{T_3 - 10}$

$\Rightarrow \frac{4}{9} = \frac{30 - T_3}{T_3 - 10}$

$\Rightarrow 4T_3 - 40 = 270 - 9T_3$

$\Rightarrow T_3 = 23.84°C$

Question138

Two thin metallic spherical shells of radii r_1 and $r_2(r_1 < r_2)$ are placed with their centres coinciding. A material of thermal conductivity K is filled in the space between the shells. The inner shell is maintained at temperature θ_1 and the outer shell at temperature $\theta_2(\theta + 1 < \theta_2)$. The rate at which heat flows radially through the material is [31 Aug 2021 Shift 2]

Options:

A. $\frac{4\pi K r_1 r_2(\theta_2 - \theta_1)}{r_2 - r_1}$

B. $\frac{\pi r_1 r_2(\theta_2 - \theta_1)}{r_2 - r_1}$

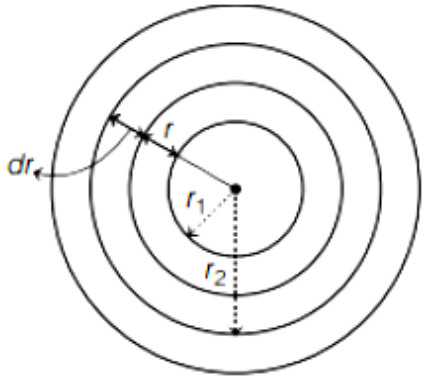
C. $\frac{K(\theta_2 - \theta_1)}{r_2 - r_1}$

D. $\frac{K(\theta_2 - \theta_1)(r_2 - r_1)}{4\pi r_1 r_2}$

Answer: A

Solution:

Solution:
Given that, r_1 and r_2 be the radii of inner and outer shells.



A material of thermal conductivity (K) is filled between region.
Consider an elementary sphere of radius r and thickness dr.
Now, thermal resistance of elementary sphere $dR = \frac{dr}{K4\pi r^2}$ [$\because$ inner surface area, $A = 4\pi r^2$]
So, total thermal resistance,

$$R = \int dR = \int_{r_1}^{r_2} \frac{dr}{4\pi K r^2} = -\frac{1}{4\pi K}\left[\frac{1}{r}\right]_{r_1}^{r_2}$$

$$R = \frac{r_2 - r_1}{4\pi K r_1 r_2}$$

Hence, heat current (or the rate of flow of heat)

$$\frac{dQ}{dt} = \frac{\Delta\theta}{R} = \frac{(\theta_2 - \theta_1)}{\frac{(r_2 - r_1)}{4\pi K r_1 r_2}} = \frac{4\pi K r_1 r_2(\theta_2 - \theta_1)}{r_2 - r_1}$$

Question139

An electric appliance supplies 6000J/min heat to the system. If the system delivers a power of 90W. How long it would take to increase the internal energy by 2.5×10^3J ?
[26 Aug 2021 Shift 1]

Options:

A. 2.5×10^2s

B. 4.1×10^1s

C. 24×10^3s

D. 2.5×10^1s

Answer: A

Solution:

Solution:
Given, heat supplied to the system,
$\frac{\Delta Q}{\Delta t} = 6000 J/min = \frac{6000}{60} J/s = 100 J/s$
Power delivered, $P = \frac{\Delta W}{t} = 90 W$
Increase in internal energy, $\Delta U = 2.5 \times 10^3 J$
From first law of thermodynamics, we have
$\Delta Q = \Delta U + \Delta W$
or $\frac{\Delta Q}{\Delta t} = \frac{\Delta U}{\Delta t} + \frac{\Delta W}{\Delta t}$ ...(i)
Substituting the given values in Eq. (i), we get
$100 = \frac{2.5 \times 10^3}{\Delta t} + 90$
$\Rightarrow 10 = \frac{2.5 \times 10^3}{\Delta t}$
$\Rightarrow \Delta t = \frac{2.5 \times 10^3}{10}$
$\Rightarrow \Delta t = 2.5 \times 10^2 s$

Question140

A sample of gas with γ = 1.5 is taken through an adiabatic process in which the volume is compressed from 1200cm^3 to 300cm^3. If the initial pressure is 200 kPa. The absolute value of the work done by the gas in the process is ..... J.
[31 Aug 2021 Shift 2]

Answer: 480

Solution:

Solution:
Given, sample of an ideal gas with (γ = 1.5) is taken through adiabatic process, where
Initial volume, $V_1 = 1200 cm^3 = 12 \times 10^{-4} m^3$
Final volume, $V_2 = 300 cm^3 = 3 \times 10^{-4} m$
Initial pressure, $p_1 = 200 kPa = 2 \times 10^5 \times Pa$
Let final pressure = p_2

Using equation of adiabatic process,

$p_1V_1^{\gamma} = \rho_2V_2^{\gamma}$

$p_2 = p_1\left(\frac{V_1}{V_2}\right)^{\gamma} = 2\times10^5\left(\frac{12\times10^{-4}}{3\times10^{-4}}\right)^{1.5}$

$= 16\times10^5\,\text{Pa}$

Work done in adiabatic process, $W = \frac{p_1V_1 - p_2V_2}{\gamma - 1}$

Substituting the values, we get

$W = \frac{2\times10^5\times12\times10^{-4} - 16\times10^5\times3\times10^{-4}}{1.5-1} = -480\text{J}$

Hence, work done in adiabatic compression is 480 J.

Question141

A reversible engine has an efficiency of $\frac{1}{4}$. If the temperature of the sink is reduced by 58°C, its efficiency becomes double. Calculate the temperature of the sink.
[31 Aug 2021 Shift 1]

Options:

A. 174°C

B. 280°C

C. 180.4°C

D. 382°C

Answer: A

Solution:

Solution:

Given, initial efficiency of engine, $\eta_1 = \frac{1}{4}$

Let, initial temperature of $\sin k = T_2$

Final temperature of $\sin k = T_2 - 58°C$

Final efficiency of engine, $\eta_2 = 2\eta_1 = \frac{2}{4} = \frac{1}{2}$

Temperature of source $= T_1$

Since, $\eta = 1 - \frac{T_2}{T_1}$

$\therefore \eta_1 = \frac{1}{4} = 1 - \frac{T_2}{T_1}$

$\Rightarrow \frac{T_2}{T_1} = 1 - \frac{1}{4}$

$\Rightarrow \frac{T_2}{T_1} = \frac{3}{4}$

$\Rightarrow T_1 = \frac{4}{3}T_2$ ...(i)

and$\eta_2 = \frac{1}{2} = 1 - \frac{T_2 - 58}{T_1}$

$\Rightarrow \frac{T_2 - 58}{T_1} = 1 - \frac{1}{2}$

$\Rightarrow \frac{T_2 - 58}{\frac{4}{3}T_2} = \frac{1}{2}$[From Eq. (i)]

$\Rightarrow 2T_2 - 116 = \frac{4}{3}T_2$

$\Rightarrow \frac{2T_2}{3} = 116$

$\Rightarrow T_2 = \frac{116 \times 3}{2} = 58 \times 3 = 174°C$

Question142

A heat engine operates between a cold reservoir at temperature T_2 = 400K and a hot reservoir at temperature T_1. It takes 300 f of heat from the hot reservoir and delivers 240J of heat to the cold reservoir in a cycle. The minimum temperature of the hot reservoir has to be ..... K.
[27 Aug 2021 Shift 2]

Answer: 500

Solution:

Solution:
Given, temperature of hot reservoir $= T_1$ Temperature of cold reservoir, $T_2 = 400K$
Heat of hot reservoir, $Q_1 = 300J$
Heat of cold reservoir, $Q_2 = 240J$
Since, efficiency $(\eta) = 1 - \frac{T_2}{T_1} = \frac{Q_1 - Q_2}{Q_1}$

$1 - \frac{T_2}{T_1} = 1 - \frac{Q_2}{Q_1}$

$\Rightarrow \ 1-\frac{400}{T_1}=1-\frac{240}{300}$

$\Rightarrow \ \frac{400}{T_1}=\frac{4}{5} \Rightarrow T_1=500K$

Question143

A refrigerator consumes an average 35W power to operate between temperature −10°C to 25°C. If there is no loss of energy, then how much average heat per second does it transfer?
[26 Aug 2021 Shift 2]

Options:

A. 263J/s

B. 298J/s

C. 350J/s

D. 35J/s

Answer: A

Solution:

Solution:
Given, power consumed by refrigerator
$P=35W=35Js^{-1}$
∴ Energy consumed by refrigerator per second, $W=35J$
Lower temperature limit, $T_L=-10°C=263K$
Higher temperature limit, $T_H=25°C=298K$
The coefficient of performance of refrigerator is given as

$$COP=\frac{T_L}{T_H-T_L}=\frac{Q}{W}$$

Here, Q is the heat transferred by the refrigerator.
Substituting the values, we get

$$\frac{263}{298-263}=\frac{Q}{35}$$

$$\Rightarrow Q=\frac{263}{35}\times 35=263J/s$$

Thus, the average heat transfer by refrigerator per second is $263Js^{-1}$.

Question144

Due to cold weather a 1m water pipe of cross-sectional area $1cm^2$ is filled with ice at −10°C. Resistive heating is used to melt the ice. Current of 0.5A is passed through 4k Omega resistance. Assuming that, all the heat produced is used for melting, what is the minimum time required?

[Given, latent heat of fusion for water/ice $= 3.33 \times 10^5 Jkg^{-1}$, specific heat of ice $= 2 \times 10^3 Jkg^{-1}$ and density of ice $= 10^3\ kg/m^3$]

[1 Sep 2021 Shift 2]

Options:

A. 0.353s

B. 35.3s

C. 3.53s

D. 70.6s

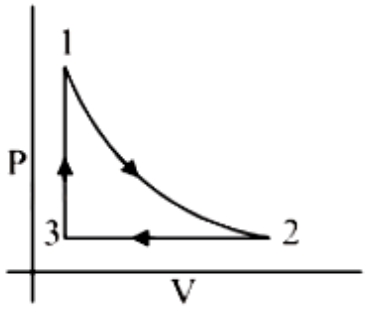
Answer: B

Solution:

Solution:
Given, the length of the water pipe, L = 1 m
The cross-sectional area of the water pipe, $A = 1cm^2 = 10^{-4}m^2$
The temperature of the ice = -10ºC
Current passing in the conductor, I = 0.5 A
Resistance of the conductor, R = 4 kΩ
The latent heat of fusion for ice, $,L_i = 3.33 \times 10^5 J/kg$
The density of the ice, $d = 1000\,kg/m^3$
The specific heat of the ice, $c_{p,\,ice} = 2 \times 10^3 J/kg$
Heat required to melt the ice at 10°C to 0°C
$Q = mc_p\Delta T + mL_i$
$Q = dVc_p\Delta T + dVL_f$
$= 1000 \times 10^{-4} \times 2 \times 10^3 \times (10) + 1000 \times 10^{-4} \times 3.33 \times 10^5$
$(\because V = A \times L)$
= 35300 J
According to the Joule's law of heating,
$H = I^2Rt$
$\Rightarrow 35300 = (0.5)^2(4000)(t)$
t = 35.3 s
Thus, the minimum time required to melt the ice is 35.3 s.

Question145

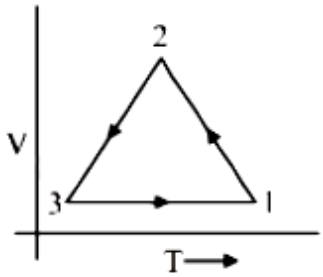
Which of the following is an equivalent cyclic process corresponding to the thermodynamic cyclic given in the figure?
where, 1 → 2 is adiabatic.
(Graphs are schematic and are not to scale)



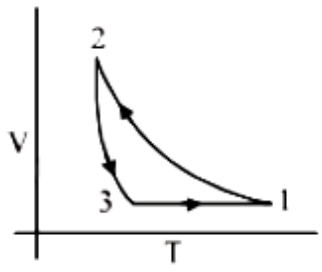
[9 Jan. 2020 I]

Options:

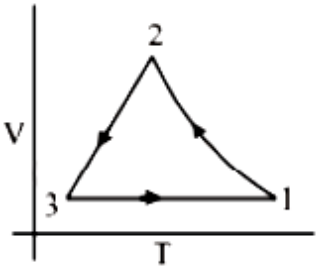
A.



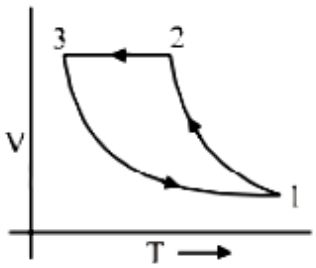
B.



C.



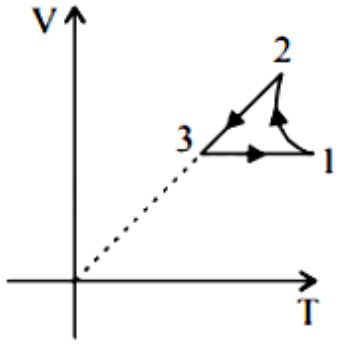
D.



Answer: C

Solution:

Solution:
For process $3 \rightarrow 1$ volume is constant
$\therefore$ Graph given in option (d) is wrong.
And process $1 \rightarrow 2$ is adiabatic $\therefore$ graph in option (1) is wrong
$\because v =$ constant
$P \uparrow, T \uparrow$
For Process $2 \rightarrow 3$ Pressure constant $i.e., P =$ constant
$\therefore V \downarrow T \downarrow$
Hence graph (c) is the correct $V - T$ graph of given $P - V$ graph



Question146

Starting at temperature 300K , one mole of an ideal diatomic gas ($\gamma = 1.4$) is first compressed adiabatically from volumeV_1 to $V_2 = \frac{V_1}{16}$. It is then allowed to expand isobarically to volume $2V_2$. If all the processes are the quasi-static then the final temperature of the gas (in °K) is (to the nearest integer) _____.
[9 Jan. 2020 II]

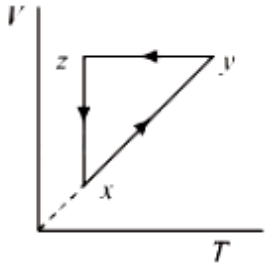
Answer: 1818

Solution:

Solution:
For an adiabatic process,
$TV^{\gamma-1} = \text{constant}$
$\therefore T_1 V_1^{\gamma-1} = T_2 V_2^{\gamma-1}$
$\Rightarrow T_2 = (300) \times \left(\frac{V_1}{\frac{V_1}{16}} \right)^{1.4-1}$
$\Rightarrow T_2 = 300 \times (16)^{0.4}$
Ideal gas equation, $PV = nRT$
$\therefore V = \frac{nRT}{P}$
$\Rightarrow V = kT$ (since pressure is constant for isobaric process)
So, during isobaric process
$V_2 = kT_2$ ...(i)
$2V_2 = kT_f$ ...(ii)
Dividing (i) by (ii)
$\frac{1}{2} = \frac{T_2}{T_f}$
$T_f = 2T_2 = 300 \times 2 \times (16)^{0.4} = 1818K$

Question147

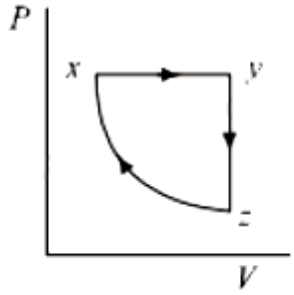
A thermodynamic cycle xyzx is shown on a V-T diagram.



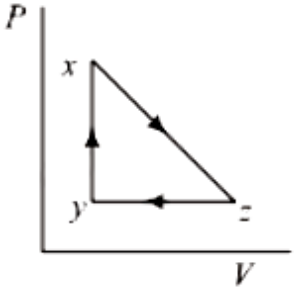
The P-V diagram that best describes this cycle is: (Diagrams are schematic and not to scale)
[8 Jan. 2020 I]

Options:

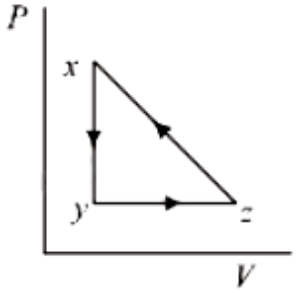
A.



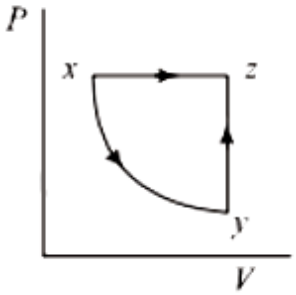
B.



C.



D.

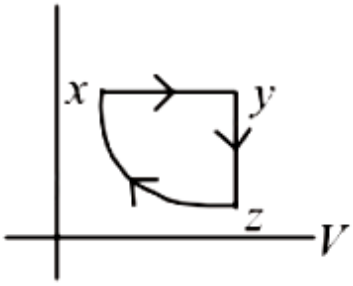


Answer: A

Solution:

Solution:
From the corresponding V-T graph given in question,
Process xy → Isobaric expansion,
Process yz → Isochoric (Pressure decreases)
Process zx → Isothermal compression

Therefore, corresponding PV graph is as shown in figure



Question148

A litre of dry air at STP expands adiabatically to a volume of 3 litres. If γ = 1.40, the work done by air is: ($3^{1.4}$ = 4.6555) [Take air to be an ideal gas]
[7 Jan. 2020 I]

Options:

A. 60.7 J

B. 90.5 J

C. 100.8 J

D. 48 J

Answer: B

Solution:

Solution:
$V_1 = 11 \Rightarrow$ initial volume, $V_1 = 1 \times 10^{-3} m^3$
$V_2 = 31 \Rightarrow$ final volume, $V_2 = 3 \times 10^{-3} m^3$
At STP:
$T = 273K$
$P_1 = 101.325 kPa \Rightarrow$ initial pressure $Y = 1.4$

Work done in adiabatic process, $\Delta W = -\left(\frac{P_2V_2 - P_1V_1}{Y - 1}\right)$

adiabatic $\Rightarrow PV^{\gamma} =$ constant

$\Rightarrow P_1V_1^{\gamma} = P_2V_2^{\gamma}$

$\Rightarrow P_2 = P_1\left(\frac{V_1}{V_2}\right)^{\gamma} = 1.01325\left(\frac{1 \times 10^{-3}}{3 \times 10^{-3}}\right)^{1.4}$

$\Rightarrow P_2 = 101.325 \times \frac{1}{(3)^{1.4}} = \left(\frac{101.325}{4.6555}\right) kPa$

$P_2 = 21.7646K\ Pa$

$\Delta W = -\left(\frac{21.7646 \times 10^3 \times 3 \times 10^{-3} - 101.325 \times 10^3 \times 1 \times 10^{-3}}{1.4 - 1} \right)$

$\Delta W = -\left(\frac{65.2937 - 101.325}{0.4} \right) = 90.5J$

Considering only magnitude, the work done by the air will be $90.5J$

Question149

Under an adiabatic process, the volume of an ideal gas gets doubled. Consequently the mean collision time betweenthe gas molecule changes from τ_1 to τ_2. If $\frac{C_p}{C_v} = \gamma$ for thisgas then a good estimate for $\frac{\tau_2}{\tau_1}$ is given by:
[7 Jan. 2020 I]

Options:

A. 2

B. $\frac{1}{2}$

C. $\left(\frac{1}{2}\right)^{\gamma}$

D. $\left(\frac{1}{2}\right)^{\frac{\gamma+1}{2}}$

Answer: D

Solution:

Solution:

Mean free path, $\lambda = \left(\frac{RT}{\sqrt{2}\pi d^2 N_A P} \right)$

$V_{rms} = \sqrt{\frac{3RT}{M}}$

$\therefore \tau = \frac{\lambda}{V_{rms}} = \frac{RT}{\sqrt{2}\pi d^2 N_A P} \times \sqrt{\frac{M}{3RT}}$

$\tau \propto \frac{\sqrt{T}}{P}$

$\frac{\tau_1}{\tau_2} = \frac{\sqrt{T_1}}{P_1} \times \frac{P_2}{\sqrt{T_2}} = \left(\frac{P_2}{P_1} \right) \sqrt{\frac{T_1}{T_2}}$

$$PV = nRT$$

$$\frac{P_1}{P_2} \times \frac{V_1}{V_2} = \frac{T_1}{T_2}$$

$$\Rightarrow 2^{\gamma} \times \frac{V}{2V} = \frac{T_1}{T_2}$$

$$\Rightarrow \frac{T_1}{T_2} = (2^{\gamma - 1})$$

$$\therefore \frac{\tau_1}{\tau_2} = \left(\frac{P_2}{P_1}\right) \times \sqrt{\frac{T_1}{T_2}} = \frac{1}{2^{\gamma}} \times \sqrt{2^{\gamma - 1}} = \frac{2^{\frac{\gamma - 1}{2}}}{2^{\gamma}}$$

$$\frac{\tau_2}{\tau_1} = \frac{2^{\gamma}}{2^{\frac{\gamma - 1}{2}}} = 2^{\gamma - \left(\frac{\gamma - 1}{2}\right)} = 2^{\frac{\gamma - 1}{2}}$$

$$\Rightarrow \frac{\tau_1}{\tau_2} = \left(\frac{1}{2}\right)^{\frac{\gamma - 1}{2}}$$

Question150

A Carnot engine having an efficiency of $\frac{1}{10}$ is being used as a refrigerator. If the work done on the refrigerator is 10 J, the amount of heat absorbed from the reservoir at lower temperature is: [8 Jan. 2020 II]

Options:

A. 99 J

B. 100 J

C. 1 J

D. 90 J

Answer: D

Solution:

Solution:
For carnot refrigerator

Efficiency $= \frac{Q_1 - Q_2}{Q_1}$

Where, $Q_1 =$ heat lost from sorrounding

$Q_2 =$ heat absorbed from reservoir at low

Also, $\frac{Q_1 - Q_2}{Q_1} = \frac{w}{Q_1}$

$\Rightarrow \frac{1}{10} = \frac{w}{Q_1}$

$\Rightarrow Q_1 = w \times 10 = 100J$

So, $Q_1 - Q_2 = w$

$\Rightarrow Q_2 = Q_1 - w$

$\Rightarrow 100 - 10 = Q_2 = 90J$

Question151

A Carnot engine operates between two reservoirs of temperatures 900 K and 300 K. The engine performs 1200 J of work per cycle. The heat energy (in J) delivered by the engine to the low temperature reservoir, in a cycle, is _____.
[NA 7 Jan. 2020 I]

Answer: 600

Solution:

Solution:

Given; $T_1 = 900K$, $T_2 = 300K$, $W = 1200J$

Using, $1 - \frac{T_2}{T_1} = \frac{W}{Q_1}$

$\Rightarrow 1 - \frac{300}{900} = \frac{1200}{Q_1}$

$\Rightarrow \frac{2}{3} = \frac{1200}{Q_1} \Rightarrow Q_1 = 1800$

Therefore heat energy delivered by the engine to the low temperature reservoir,

$Q_2 = Q_1 - W = 1800 - 1200 = 600.00J$

Question152

Two ideal Carnot engines operate in cascade (all heat given up by one engine is used by the other engine to produce work) between temperatures, T_1 and T_2. The temperature of the hot reservoir of the

first engine is T_1 and the temperature of the cold reservoir of the second engine is T_2. T is temperature of the sink of first engine which is also the source for the second engine. How is T related to T_1, and T_2, if both the engines perform equal amount of work?
[7 Jan. 2020 II]

Options:

A. $T = \frac{2T_1T_2}{T_1+T_2}$

B. $T = \frac{T_1+T_2}{2}$

C. $T = \sqrt{T_1T_2}$

D. $T = 0$

Answer: B

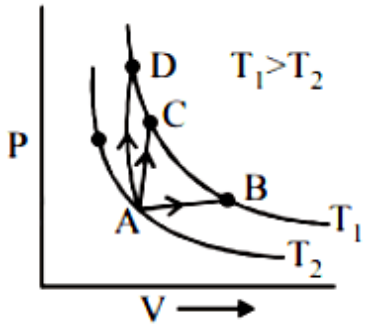
Solution:

Solution:
Let Q_H = Heat taken by first engine
Q_L = Heat rejected by first engine
Q_2 = Heat rejected by second engine
Work done by 1^{st} engine = work done by 2^{nd} engine
$W = Q_H - Q_L = Q_L - Q_2 \Rightarrow 2Q_L = Q_H + Q_2$
$2 = \frac{\theta_H}{\theta_L} + \frac{\theta_2}{\theta_L}$
Let T be the temperature of cold reservoir of first engine. Then in carnot engine.
$\frac{Q_H}{Q_L} = \frac{T_1}{T}$ and $\frac{Q_L}{Q_2} = \frac{T}{T_2}$
$\Rightarrow 2 = \frac{T_1}{T} + \frac{T_2}{T}$ using (i)
$\Rightarrow 2T = T_1 + T_2 \Rightarrow T = \frac{T_1+T_2}{2}$

Question153

Three different processes that can occur in an ideal monoatomic gas are shown in the P vs V diagram. The paths are lebelled as

A → B, A → C and A → D. The change in internal energies during these process are taken as E_{AB}, E_{AC} and E_{AD} and the work done as W_{AB}, W_{AC} and W_{AD}The correct relation between these parameters are:



[5 Sep. 2020 (I)]

Options:

A. $E_{AB} = E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} < 0$

B. $E_{AB} = E_{AC} = E_{AD}$, $W_{AB} > 0$, $W_{AC} = 0$, $W_{AD} > 0$

C. $E_{AB} < E_{AC} < E_{AD}$, $W_{AB} > 0$, $W_{AC} > W_{AD}$

D. $E_{AB} > E_{AC} > E_{AD}$, $W_{AB} < W_{AC} < W_{AD}$

Answer: B

Solution:

Solution:
Temperature change ΔT is same for all three processes
$A \rightarrow B$; $A \rightarrow C$ and $A \rightarrow D$
$\Delta U = nC_v\Delta T =$ same
$E_{AB} = E_{AC} = E_{AD}$
Work done, $W = P \times \Delta V$
$AB \rightarrow$ volume is increasing $\Rightarrow W_{AB} > 0$
$AD \rightarrow$ volume is decreasing $\Rightarrow W_{AD} < 0$
$AC \rightarrow$ volume is constant $\Rightarrow W_{AC} = 0$

Question154

In an adiabatic process, the density of a diatomic gas becomes 32 times its initial value. The final pressure of the gas is found to be n

times the initial pressure. The value of n is :
[5 Sep. 2020 (II)]

Options:

A. 32

B. 326

C. 128

D. $\frac{1}{32}$

Answer: C

Solution:

Solution:
In adiabatic process
$PV^{\gamma} =$ constant
$\therefore P\left(\frac{m}{\rho}\right)^{\gamma} =$ constant $\left(\because V = \frac{m}{\rho}\right)$
As mass is constant
$\therefore P \propto \rho^{\gamma}$
If P_i and P_f be the initial and final pressure of the gas and ρ_i and ρ_f be the initial and final density of the gas. Then
$\frac{P_f}{P_i} = \left(\frac{\rho_f}{\rho_i}\right)^{\gamma} = (32)^{7/5}$
$\Rightarrow \frac{nP_i}{P_i} = (2^5)^{7/5} = 2^7$
$\Rightarrow n = 2^7 = 128$

Question155

Match the thermodynamic processes taking place in a system with the correct conditions. In the table : ΔQ is the heat supplied, ΔW is

the work done and ΔU is change in internal energy of the system.

Process	Condition
(I) Adiabatic	(A) $\Delta W = 0$
(II) Isothermal	(B) $\Delta Q = 0$
(III) Isochoric	(C) $\Delta U \neq 0, \Delta W \neq 0, \Delta Q \neq 0$
IV) Isobaric	(D) $\Delta U = 0$

[4 Sep. 2020 (II)]

Options:

A. (I)-(A), (II)-(B), (III)-(D), (IV)-(D)

B. (I)-(B), (II)-(A), (III)-(D), (IV)-(C)

C. (I)-(A), (II)-(A), (III)-(B), (IV)-(C)

D. (I)-(B), (II)-(D), (III)-(A), (IV)-(C)

Answer: D

Solution:

Solution:
(I) Adiabatic process : No exchange of heat takes place with surroundings.
$\Rightarrow \Delta Q = 0$
(II) Isothermal process : Temperature remains constant
$\therefore \Delta T = 0 \Rightarrow \Delta U = \frac{f}{2} nR\Delta T \Rightarrow \Delta U = 0$
No change in internal energy $[\Delta U = 0]$
(III) Isochoric process volume remains constant
$\Delta V = 0 \Rightarrow W = \int P \, . \, d V = 0$
Hence work done is zero.
(IV) In isobaric process pressure remains constant.
$W = P \, . \, \Delta V \neq 0$
$\Delta U = \frac{f}{2} nR\Delta T = \frac{f}{2}[P\Delta V] \neq 0$
$\therefore \Delta Q = nC_p \Delta T \neq 0$

Question156

A balloon filled with helium (32°C and 1.7 atm.) bursts. Immediately afterwards the expansion of helium can be considered as :
[3 Sep. 2020 (I)]

Options:

A. irreversible isothermal

B. irreversible adiabatic

C. reversible adiabatic

D. reversible isotherm7al

Answer: B

Solution:

Solution:
Bursting of helium balloon is irreversible and in this process $\Delta Q = 0$, so adiabatic.

Question157

An engine takes in 5 mole of air at 20°C and 1 atm, and compresses it adiabaticaly to 1/10th of the original volume. Assuming air to be a diatomic ideal gas made up of rigid molecules, the change in its internal energy during this process comes out to be X kJ. The value of X to the nearest integer is _____.
[NA 2 Sep. 2020 (I)]

Answer: 46

Solution:

Solution:
For adiabatic process, $TV^{\gamma-1} =$ constant
or ,$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$T_1 = 20°\text{nd}\ \ \gamma = \frac{7}{5}$

$T_1(V_1)^{\gamma-1} = T_2\left(\frac{V_1}{10}\right)^{\gamma-1}$

$\Rightarrow 293 = T_2\left(\frac{1}{10}\right)^{2/5} \Rightarrow T_2 = 293(10)^{2/5} \simeq 736\text{K}$

$\Delta T = 736 - 293 = 443\text{K}$

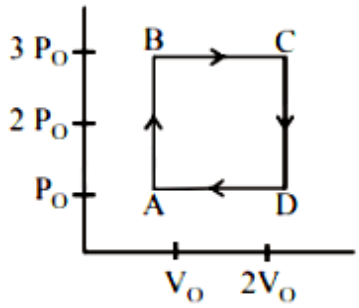
During the process, change in internal energy

$\Delta U = N C_V \Delta T = 5 \times \frac{5}{2} \times 8.3 \times 443 \simeq 46 \times 10^3\text{J} = X\,\text{kJ}$

$\therefore X = 46$

Question158

An engine operates by taking a monatomic ideal gas through the cycle shown in the figure. The percentage efficiency of the engine is close is _____.

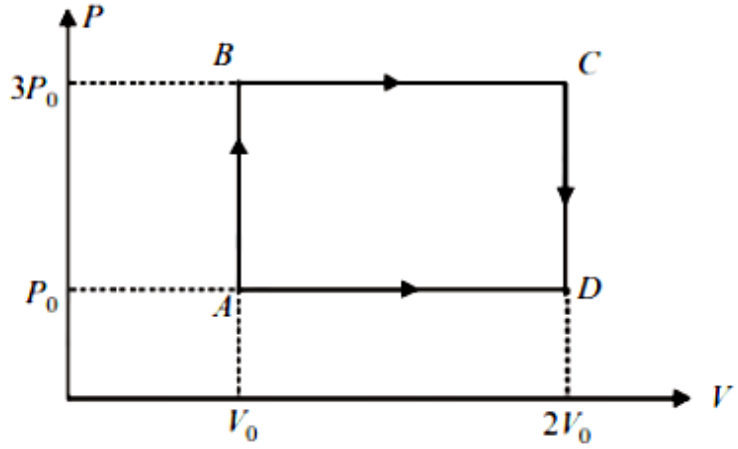


[NA 6 Sep. 2020 (II)]

Answer: 19

Solution:

Solution:



From the figure,
Work, $W = 2P_0V_0$

Heat given, $Q_{in} = W_{AB} + W_{BC} = n \cdot C_V \Delta T_{AB} + nC_P \Delta T_{BC}$

$= n\frac{3R}{2}(T_B - T_A) + \frac{n5R}{2}(T_C - T_B)$ $\left(\because C_v = \frac{3R}{2} \text{ and } C_P = \frac{5R}{2} \right)$

$= \frac{3}{2}(P_BV_B - P_AV_A) + \frac{5}{2}(P_CV_C - P_BV_B)$

$= \frac{3}{2} \times [3P_0V_0 - P_0V_0] + \frac{5}{2}[6P_0V_0 - 3P_0V_0]$

$= 3P_0V_0 + \frac{15}{2}P_0V_0 = \frac{21}{2}P_0V_0$

Efficiency, $\eta = \frac{W}{Q_{in}} = \frac{2P_0V_0}{\frac{21}{2}P_0V_0} = \frac{4}{21}$

$\eta\% = \frac{400}{21} \approx 19$

Question159

If minimum possible work is done by a refrigerator in converting 100 grams of water at 0°C to ice, how much heat (in calories) is released to the surroundings at temperature 27°C (Latent heat of ice = 80 Cal/gram) to the nearest integer?
[NA 3 Sep. 2020 (II)]

Answer: 8791

Solution:

Solution:

Given,
Heat absorbed, $Q_2 = mL = 80 \times 100 = 8000$ Cal
Temperature of ice, $T_2 = 273K$
Temperature of surrounding,
$T_1 = 273 + 27 = 300K$

Efficiency $= \frac{w}{Q_2} = \frac{Q_1 - Q_2}{Q_2} = \frac{T_1 - T_2}{T_2} = \frac{300 - 273}{273}$

$\Rightarrow \frac{Q_1 - 8000}{8000} = \frac{27}{273} \Rightarrow Q_1 = 8791$ Cal

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Question160

A heat engine is involved with exchange of heat of 1915 J, – 40 J, +125 J and – Q J, during one cycle achieving an efficiency of 50.0%. The value of Q is :
[2 Sep. 2020 (II)]

Options:

A. 640 J

B. 40 J

C. 980 J

D. 400 J

Answer: C

Solution:

Solution:
Efficiency, $\eta = \frac{\text{Work done}}{\text{Heat absorbed}} = \frac{W}{\sum Q}$

$= \frac{Q_1 + Q_2 + Q_3 + Q_4}{Q_1 + Q_3} = 0.5$

Here, $Q_1 = 1915J$, $Q_2 = -40J$ and $Q_3 = 125J$

$\therefore \frac{1915 - 40 + 125 + Q_4}{1915 + 125} = 0.5$

$\Rightarrow 1915 - 40 + 125 + Q_4 = 1020$

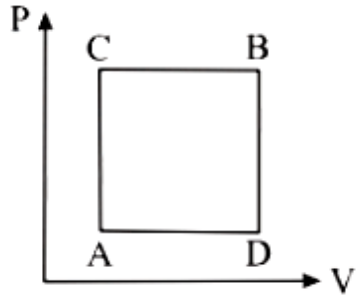
$\Rightarrow Q_4 = 1020 - 2000$

$\Rightarrow Q_4 = -Q = -980J$

$\Rightarrow Q = 980J$

Question161

A gas can be taken from A to B via two different processes ACB and ADB.



When path ACB is used 60 J of heat flows into the system and 30J of work is done by the system. If path ADB is used work done by the system is 10 J. The heat Flow into the system in path ADB is : [9 Jan. 2019 I]

Options:

A. 40 J

B. 80 J

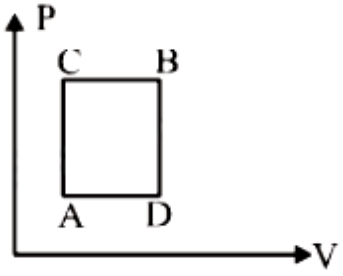
C. 100 J

D. 20 J

Answer: A

Solution:

Solution:



Δ U remains same for both paths ACB and ADB

$\Delta Q_{ACB} = \Delta W_{ACB} + \Delta U_{ACB}$

$\Rightarrow 60J = 30J + \Delta U_{ACB}$

$\Rightarrow U_{ACB} = 30J$

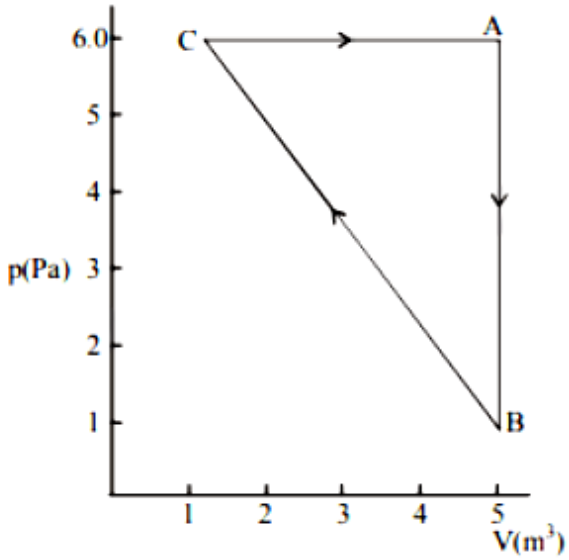
$\therefore \Delta U_{ADB} = \Delta U_{ACB} = 30J$

$\Delta Q_{ADB} = \Delta U_{ADB} + \Delta W_{ADB}$

$= 10J + 30J = 40J$

Question162

For the given cyclic process CAB as shown for gas, the work done is:



[12 Jan. 2019 I]

Options:

A. 30 J

B. 10 J

C. 1 J

D. 5 J

Answer: B

Solution:

Solution:
Total work done by the gas during the cycle is equal to area of triangle ABC.

$\therefore \Delta W = \frac{1}{2} \times 4 \times 5 = 10J$

Question163

A rigid diatomic ideal gas undergoes an adiabatic process at room temperature. The relation between temperature and volume for this

process is $T V^{x} =$ constant, then x is:
[11 Jan. 2019 I]

Options:

A. $\frac{3}{5}$

B. $\frac{2}{5}$

C. $\frac{2}{3}$

D. $\frac{5}{3}$

Answer: B

Solution:

Solution:
Equation of adiabatic change is
$T V^{\gamma - 1} = \text{constant}$
Put $\gamma = \frac{7}{5}$, we get: $\gamma - 1 = \frac{7}{5} - 1$
$\therefore x = \frac{2}{5}$

Question164

Half mole of an ideal monoatomic gas is heated at constant pressure of 1 atm from 20°C to 90°C. Work done by gas is close to: (Gas constant R = 8.31 J/mol-K)
[10 Jan. 2019 II]

Options:

A. 581 J

B. 291 J

C. 146 J

D. 73 J

Answer: B

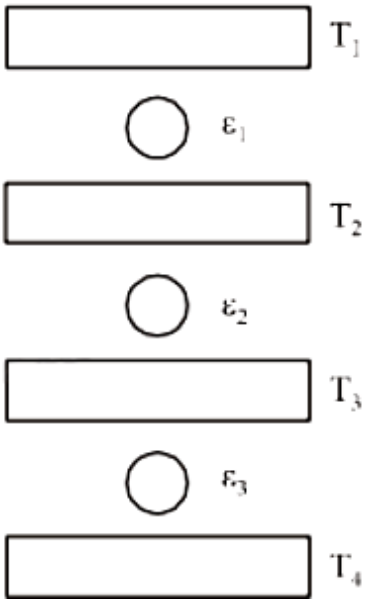
Solution:

Solution:
Work done,

$$W = P\Delta V = nR\Delta T = \frac{1}{2} \times 8.31 \times 70 \simeq 291J$$

Question165

Three Carnot engines operate in series between a heat source at a temperature T_1 and a heat sink at temperature T_4 (see figure). There are two other reservoirs at temperature T_2 and T_3, as shown, with $T_1 > T_2 > T_3 > T$ (4) The three engines are equally efficient if:



[10 Jan. 2019 I]

Options:

A. $T_2 = (T_1 T_4)^{1/2}$; $T_3 = (T_1^2 T_4)^{1/3}$

B. $T_2 = (T_1^2 T_4)^{1/3}$; $T_3 = (T_1 T_4^2)^{1/3}$

C. $T_2 = (T_1 T_4^2)^{1/3}$; $T_3 = (T_1^2 T_4)^{1/3}$

D. $T_2 = (T_1^3 T_4)^{1/4}$; $T_3 = (T_1 T_4^3)^{1/4}$

Answer: B

Solution:

Solution:
According to question, $\eta_1 = \eta_2 = \eta_3$

$\therefore 1 - \frac{T_2}{T_1} = 1 - \frac{T_3}{T_2} = 1 - \frac{T_4}{T_3}$

[∵ Three engines are equally efficient]

$\Rightarrow \frac{T_2}{T_1} = \frac{T_3}{T_2} = \frac{T_4}{T_3}$

$\Rightarrow T_2 = \sqrt{T_1 T_3}$

$T_3 = \sqrt{T_2 T_4}$

From (i) and (ii)

$T_2 = (T_1^2 T_4)^{1/3}$

$T_3 = (T_1 T_4^2)^{1/3}$

Question166

Two Carnot engines A and B are operated in series. The first one, A receives heat at T_1(= 600K) and rejects to a reservoir at temperature T_2. The second engine B receives heat rejected by the first engine and in turn, rejects to a heat reservoir at T_3(= 400K). Calculate the temperature T_2 if the work outputs of the two engines are equal:
[9 Jan. 2019 II]

Options:

A. 600 K

B. 400 K

C. 300 K

D. 500 K

Answer: D

Solution:

Solution:

$\eta_A = \frac{T_1 - T_2}{T_1} = \frac{w_A}{Q_1}$

and, $\eta_B = \frac{T_2 - T_3}{T_2} = \frac{W_B}{Q_2}$

According to question,

$W_A = W_B$

$\therefore \frac{Q_1}{Q_2} = \frac{T_1}{T_2} \times \frac{T_2 - T_3}{T_1 - T_2} = \frac{T_1}{T_2}$

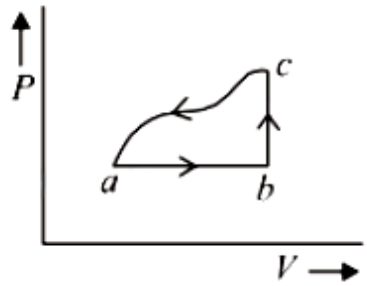
$\therefore T_2 = \frac{T_1 + T_3}{2}$

$= \frac{600 + 400}{2}$

$= 500K$

Question167

A sample of an ideal gas is taken through the cyclic process abca as shown in the figure. The change in the internal energy of the gas along the path ca is – 180 J, The gas absorbs 250 J of heat along the path ab and 60 J along the path bc. The work down by the gas along the path abc is:



[12 Apr. 2019 I]

Options:

A. 120 J

B. 130 J

C. 100 J

D. 140 J

Answer: B

Solution:

Solution:

$\Delta U_{ac} = -(\Delta U_{ca}) = -(-180) = 180J$
$Q = 250 + 60 = 310J$
Now $Q = \Delta U + W$
or $310 = 180 + W$
or $W = 130J$

Question168

A cylinder with fixed capacity of 67.2 lit contains helium gas at STP. The amount of heat needed to raise the temperature of the gas by 20oC is : [Given that R = 8.31 $Jmol^{-1}$ K^{-1}]
[10 Apr. 2019 I]

Options:

A. 350 J

B. 374 J

C. 748 J

D. 700 J

Answer: C

Solution:

Solution:
As the process is isochoric so,
$Q = nc_v\Delta T = \frac{67.2}{22.4} \times \frac{3R}{2} \times 20 = 90R = 90 \times 8.31 \simeq 748J$

Question169

n moles of an ideal gas with constant volume heat capacity C_V undergo an isobaric expansion by certain volume. The ratio of the work done in the process, to the heat supplied is:
[10 Apr. 2019 I]

Options:

A. $\frac{nR}{C_V + nR}$

B. $\frac{nR}{C_V - nR}$

C. $\frac{4nR}{C_V - nR}$

D. $\frac{4nR}{C_V + nR}$

Answer: A

Solution:

Solution:
At constant volume
Work done
$(W) = nR\Delta T$
Heat given $Q = C_v\Delta T + nR\Delta T$
So, $\therefore \frac{W}{Q} = \frac{nR\Delta T}{C_v\Delta T + nR\Delta T} = \frac{nR}{C_V + nR}$

Question170

One mole of an ideal gas passes through a process where pressure and volume obey the relation $P = P_0\left[1 - \frac{1}{2}\left(\frac{V_0}{V}\right)^2\right]$.
Here P and V_0 are constants. Calculate the charge in the temperature of the gas if its volume changes from V_o to $2V_o$.
[10 Apr. 2019 II]

Options:

A. $\frac{1}{2}\frac{P_oV_o}{R}$

B. $\frac{5}{4}\frac{P_oV_o}{R}$

C. $\frac{3}{4}\frac{P_oV_o}{R}$

D. $\frac{1}{4}\frac{P_o V_o}{R}$

Answer: B

Solution:

Solution:
We have given,

$P = P_0\left[1 - \frac{1}{2}\left(\frac{V_0}{V}\right)^2\right]$

When $V_1 = V_0$

$\Rightarrow P_1 = P_0\left[1 - \frac{1}{2}\right] = \frac{P_0}{2}$

When $V_2 = 2V_0$

$\Rightarrow P_2 = P_0\left[1 - \frac{1}{2}\left(\frac{1}{4}\right)\right] = \left(\frac{7P_0}{8}\right)$

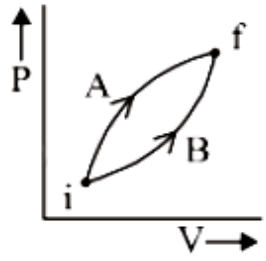
$\Delta T = T_2 - T_1 = \left|\frac{P_1V_1}{nR} - \frac{P_2V_2}{nR}\right| \left[\because T = \frac{PV}{nR}\right]$

$\Delta T = \left|\left(\frac{1}{nR}\right)(P_1V_1 - P_2V_2)\right| = \left(\frac{1}{nR}\right)\left|\left(\frac{P_0V_0}{2} - \frac{7P_0V_0}{4}\right)\right|$

$= \frac{5P_0V_0}{4nR} = \frac{5P_0V_0}{4R}(\because n = 1)$

Question171

Following figure shows two processes A and B for a gas. If ΔQ_A and ΔQ_B are the amount of heat absorbed by the system in two cases, and ΔU_A and ΔU_B are changes in internal energies, respectively, then:



[9 April 2019 I]

Options:

A. $\Delta Q_A < \Delta Q_B$, $\Delta U_A < \Delta U_B$

B. $\Delta Q_A > \Delta Q_B$, $\Delta U_A > \Delta U_B$

C. $\Delta Q_A > \Delta Q_B$, $\Delta U_A = \Delta U_B$

D. $\Delta Q_A = \Delta Q_B$; $\Delta U_A = \Delta U_B$

Answer: C

Solution:

Solution:
Internal energy depends only on initial and final state
So, $\Delta U_A = \Delta U_B$
Also $\Delta Q = \Delta U + W$
AS $W_A > W_B \Rightarrow \Delta Q_A > \Delta Q_B$

Question172

A thermally insulted vessel contains 150g of water at 0°C. Then the air from the vessel is pumped out adiabatically. A fraction of water turns into ice and the rest evaporates at 0°C itself. The mass of evaporated water will be closed to:(Latent heat of vaporization of water $= 2.10 \times 10^6 J\ kg^{-1}$ and Latent heat of Fusion of water $= 3.36 \times 10^5 J\ kg^{-1}$)
[8 April 2019 I]

Options:

A. 150 g

B. 20 g

C. 130 g

D. 35 g

Answer: B

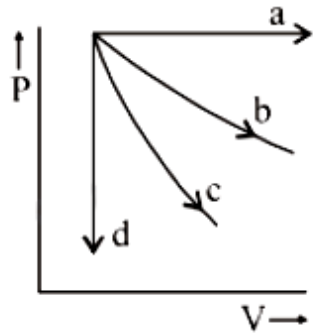
Solution:

Solution:
Suppose amount of water evaporated be M gram.
Then $(150 - M)$ gram water converted into ice.
so, heat consumed in evoporation = Heat released in fusion
$M \times L_v = (150 - M) \times L$

$M \times 2.1 \times 10^6 = (150 - M) \times 3.36 \times 10^5$
$\Rightarrow M = 20g$

Question173

The given diagram shows four processes i.e., isochoric, isobaric, isothermal and adiabatic. The correct assignment of the processes, in the same order is given by :



[8 April 2019 II]

Options:

A. a d b c

B. d a c b

C. a d c b

D. d a b c

Answer: D

Solution:

Solution:
a → Isobasic, b → Isothermal, c → Adiabatic, d → Isochoric

Question174

A Carnot engine has an efficiency of 1/6. When the temperature of the sink is reduced by 62°C, its efficiency is doubled. The temperatures of the source and the sink are, respectively.
[12 Apr. 2019 II]

Options:

A. 62°C, 124°C

B. 99°C, 37°C

C. 124°C, 62°C

D. 37°C, 99°C

Answer: B

Solution:

Solution:

Using, $n = 1 - \frac{T_2}{T_1}$

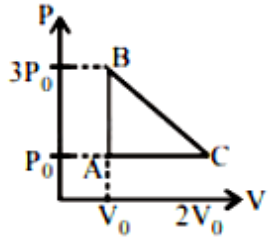
$n = \frac{1}{6} = 1 - \frac{T_2}{T_1}$

and $\frac{T}{3} = 1 - \frac{T_2 - 62}{T_1}$

On solving, we get $T_1 = 99°C$ and $T_2 = 37°C$

Question175

One mole of an ideal monoatomic gas is taken along the path ABCA as shown in the PV diagram. The maximum temperature attained by the gas along the path BC is given by



[Online April 16, 2018]

Options:

A. $\frac{25}{8}\frac{P_0V_0}{R}$

B. $\frac{25}{4}\frac{P_0V_0}{R}$

C. $\frac{25}{16}\frac{P_0V_0}{R}$

D. $\frac{5}{8}\frac{P_0V_0}{R}$

Answer: A

Solution:

Solution:
Equation of the BC

$$P = P_0 - \frac{2P_0}{V_0}(V - 2V_0)$$

using $PV = nRT$

$$\text{Temperature, } T = \frac{P_0V - \frac{2P_0V^2}{V_0} + 4P_0 \sim V}{1 \times R}$$

$(\because n = 1 \text{ mole given})$

$$T = \frac{P_0}{F}\left[5V - \frac{2V^2}{V_0}\right]$$

$$\frac{dT}{dV} = 0 \Rightarrow 5 - \frac{4V}{V_0} = 0 \Rightarrow V = \frac{5}{4}V_0$$

$$T = \frac{P_0}{R}\left[5 \times \frac{5V_0}{4} - \frac{2}{V_0} \times \frac{25}{16}V_0^2\right] = \frac{25}{8}\frac{P_0V_0}{R}$$

Question176

One mole of an ideal monoatomic gas is compressed isothermally in a rigid vessel to double its pressure at room temperature, 27°C. The work done on the gas will be:
[Online April 15, 2018]

Options:

A. 300R ln 6

B. 300R

C. 300R ln 7

D. 300R ln 2

Answer: D

Solution:

Solution:

Work done on gas $= nRT\ln\left(\frac{p_f}{p_1}\right) = R(300)\ln(2)$

$= 300R\ln 2\left(\because \frac{P_f}{p_i} = 2 \text{ given}\right)$

Question177

A Carnot's engine works as a refrigerator between 250 K and 300 K. It receives 500 cal heat from the reservoir at the lower temperature. The amount of work done in each cycle to operate the refrigerator is: [Online April 15, 2018]

Options:

A. 420 J

B. 2100 J

C. 772 J

D. 2520 J

Answer: A

Solution:

Solution:
Given: Temperature of cold body, $T_2 = 250K$ temperature of hot body; $T_1 = 300K$
Heat received, $Q_2 = 500$ cal work done, $W = ?$

Efficiency $= 1 - \frac{T_2}{T_1} = \frac{W}{Q_2 + W} \Rightarrow 1 - \frac{250}{300} = \frac{W}{Q_2 + W}$

$W = \frac{Q_2}{5} = \frac{500 \times 4.2}{5}J = 420J$

Question178

Two Carnot engines A and B are operated in series. Engine A receives heat from a reservoir at 600K and rejects heat to a reservoir at

temperature T . Engine B receives heat rejected by engine A and in turn rejects it to a reservoir at 100K . If the efficiencies of the two engines A and B are represented by η_A and η_B respectively, then what is the value of $\frac{\eta_A}{\eta_B}$

[Online April 15, 2018]

Options:

A. $\frac{12}{7}$

B. $\frac{12}{5}$

C. $\frac{5}{12}$

D. $\frac{7}{12}$

Answer: D

Solution:

Solution:

(d) Efficiency of engine A, $n_A = \frac{T_1 - T_2}{T_1}$

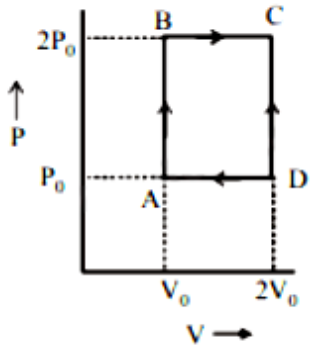
and $n_B = \frac{T_2 - T_3}{T_2}$; $T_2 = \frac{T_1 + T_3}{2} = 350K$

or $\frac{n_A}{n_B} = \frac{\frac{600-350}{600}}{\frac{350-100}{350}} = \frac{7}{12}$

Question179

An engine operates by taking n moles of an ideal gas through the cycle ABCDA shown in figure. The thermal efficiency of the engine is

: (Take C_v = 1.5 R, where R is gas constant)



[Online April 8, 2017]

Options:

A. 0.24

B. 0.15

C. 0.32

D. 0.08

Answer: B

Solution:

Solution:
Work-done $(W) = P_0V_0$
According to principle of calorimetry
Heat given $= Q_{AB} = Q_{BC}$

$$= nC_v dT_{AB} + nC_P dT_{BC}$$

$$= \frac{3}{2}(nRT_B - nRT_A) + \frac{5}{2}(nRT_C - nRT_B)$$

$$= \frac{3}{2}(2P_0V_0 - P_0V_0) + \frac{5}{2}(4P_0V_0 - 2P_0V)$$

$$= \frac{13}{2}P_0V_0$$

Thermal efficiency of engine $(\eta) = \frac{W}{Q_{given}} = \frac{2}{13} = 0.15$

Question180

200g water is heated from 40°C to 60°C. Ignoring the slight expansion of water, the change in its internal energy is close to (Given

specific heat of water = 4184 J/kgK):
[Online April 9, 2016]

Options:

A. 167.4 kJ

B. 8.4 kJ

C. 4.2 kJ

D. 16.7 kJ

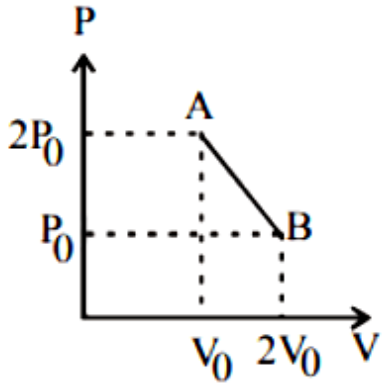
Answer: D

Solution:

Solution:
Volume of water does not change, no work is done on or by the system $(W = 0)$
According to first law of thermodynamics
$Q = \Delta U + W$
For Isochoric process $Q = \Delta U$
$\Delta U = \mu cd\, T = 2 \times 4184 \times 20 = 16.7kJ$

Question181

'n' moles of an ideal gas undergoes a process A → B as shown in the figure. The maximum temperature of the gas during the process will be :



[2016]

Options:

A. $\frac{9P_0V_0}{2nR}$

B. $\frac{9P_0V_0}{nR}$

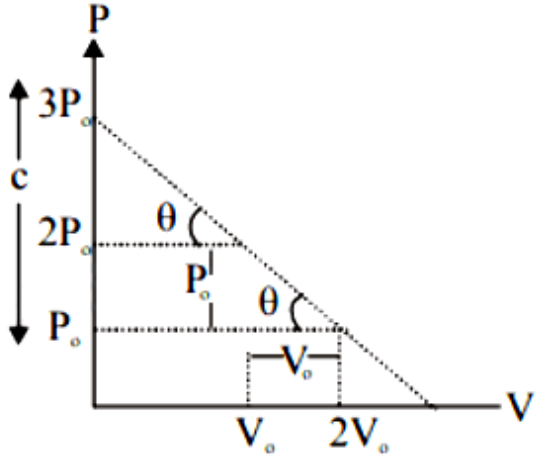
C. $\frac{9P_0V_0}{4nR}$

D. $\frac{3P_0V_0}{2nR}$

Answer: C

Solution:

Solution:
The equation for the line is



$P = \frac{-P_0}{V_0}V + 3P \left[\text{slope} = \frac{-P_0}{V_0}, c = 3P_0 \right]$

$PV_0 + P_0V = 3P_0V_0$ ...(i)

But $pV = nRT$

$\therefore P = \frac{nRT}{V}$ ...(ii)

From (i) & (ii)

$\frac{nRT}{V}V_0 + P_0V = 3P_0V_0$

From(i) & (ii)

$\frac{nRT}{V}V_0 + P_0V = 3P_0V_0$

$\therefore nRT\,V_0 + P_0V^2 = 3P_0V_0V$

For temperature to be maximum $\frac{dT}{dV} = 0$

Differentiating e.q. (iii) by ' V ' we get

$nRV_0\frac{dT}{dV} + P_0(2V) = 3P_0V_0$

$\therefore nRV_0\frac{dT}{dV} = 3P_0V_0 - 2P_0V$

$\frac{dT}{dV} = \frac{3P_0V_0 - 2P_0V}{nRV_0} = 0$

$V = \frac{3V_0}{2} \quad \therefore P = \frac{3P_0}{2}$ [From (i)]

$\therefore T_{max} = \frac{9P_0V_0}{4nR}$ [From (iii)]

Question182

The ratio of work done by an ideal monoatomic gas to the heat supplied to it in an isobaric process is : [Online April 9, 2016]

Options:

A. $\frac{2}{5}$

B. $\frac{3}{2}$

C. $\frac{3}{5}$

D. $\frac{2}{3}$

Answer: A

Solution:

Solution:
Efficiency of heat engine is given by

$\eta = \frac{w}{Q} = 1 - \frac{C_V}{C_P} = \frac{R}{C_p} = \frac{R}{\frac{5R}{2}} = \frac{2}{5}$

$(\because C_p - C_v = R)$

For monoatomic gas $C_P = \frac{5}{2}R$.

Question183

A Carnot freezer takes heat from water at 0°C inside it and rejects it to the room at a temperature of 27°C. The latent heat of ice is $336 \times 10^3 J\ kg^{-1}$. If 5kg of water at 0°C is converted into ice at 0°C by

the freezer, then the energy consumed by the freezer is close to : [Online April 10, 2016]

Options:

A. $1.51 \times 10^5 J$

B. $1.68 \times 10^6 J$

C. $1.71 \times 10^7 J$

D. $1.67 \times 10^5 J$

Answer: D

Solution:

Solution:

$\Delta H = mL = 5 \times 336 \times 10^3 = Q_{sink}$

$\frac{Q_{sink}}{Q_{source}} = \frac{T_{sink}}{T_{source}}$

$\therefore Q_{source} = \frac{T_{source}}{T_{sink}} \times Q_{sink}$

Energy consumed by freezer

$\therefore w_{output} = Q_{source} - Q_{sink} = Q_{sink}\left(\frac{T_{source}}{T_{sink}} - 1\right)$

Given: $T_{source} = 27°C + 273 = 300K$

$T_{sink} = 0°C + 273 = 273k$

$W_{output} = 5 \times 336 \times 10^3\left(\frac{300}{273} - 1\right) = 1.67 \times 10^5 J$

Question184

Consider an ideal gas confined in an isolated closed chamber. As the gas undergoes an adiabatic expansion, the average time of collision between molecules increases as V q where V is the volume of the gas.

The value of q is: $\left(\gamma = \frac{C_p}{C_v}\right)$

[2015]

Options:

A. $\frac{\gamma+1}{2}$

B. $\frac{\gamma-1}{2}$

C. $\frac{3\gamma+5}{6}$

D. $\frac{3\gamma-5}{6}$

Answer: A

Solution:

Solution:

$\tau = \frac{1}{\sqrt{2}\pi d^2 \left(\frac{N}{V}\right) \sqrt{\frac{3RT}{M}}}$

$\mu \frac{V}{\sqrt{T}}$

As, $T V^{\gamma-1} = K$

So, $\tau \propto V^{\gamma+1/2}$

Therefore, $q = \frac{\gamma+1}{2}$

Question185

Consider a spherical shell of radius R at temperature T . The black body radiation inside it can be considered as an ideal gas of photons with internal energy per unit volume $u = \frac{U}{V} \propto T^4$ and pressure $p = \frac{1}{3}\left(\frac{U}{V}\right)$. If the shell now undergoes an adiabatic expansion the relation between T and R is:
[2015]

Options:

A. $T \propto \frac{1}{R}$

B. $T \propto \frac{1}{R^3}$

C. $T \propto e^{-R}$

D. $T \propto e^{-3R}$

Answer: A

Solution:

Solution:

As, $P = \frac{1}{3}\left(\frac{U}{V}\right)$

But $\frac{U}{V} = K T^4$

So, $P = \frac{1}{3} K T^4$

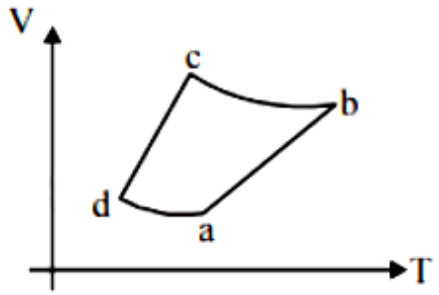
or $\frac{uRT}{V} = \frac{1}{3} K T^4 \left[\text{As } PV = uRT \right]$

$\frac{4}{3} pR^3 T^3 = \text{ constant}$

Therefore, $T \propto \frac{1}{R}$

Question186

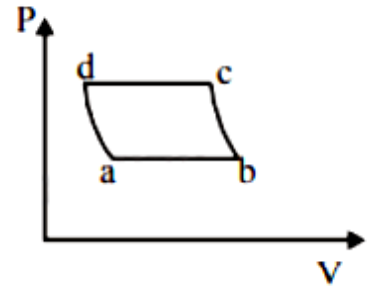
An ideal gas goes through a reversible cycle a→b→c→d has the V - T diagram shown below. Process d®a and b→c are adiabatic.



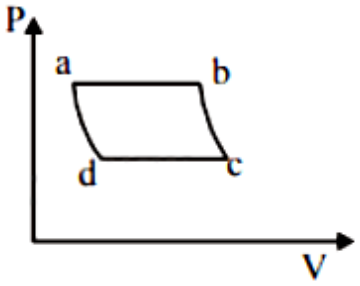
The corresponding P - V diagram for the process is (all figures are schematic and not drawn to scale) :
[Online April 10, 2015]

Options:

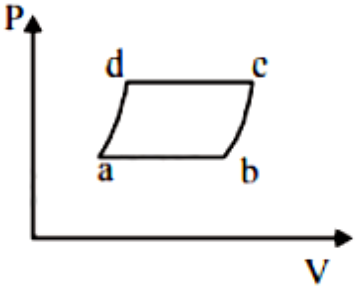
A.



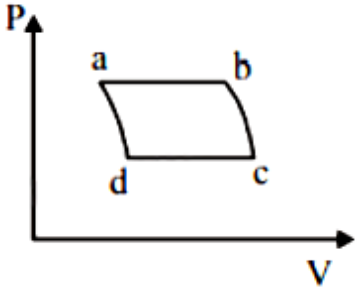
B.



C.



D.



Answer: B

Solution:

Solution:
In VT graph
ab-process : Isobaric, temperature increases.
bc process : Adiabatic, pressure decreases.
cd process : Isobaric, volume decreases.

da process : Adiabatic, pressure increases.
The above processes correctly represented in P-V diagram (b).

Question187

A solid body of constant heat capacity 1 J/°C is being heated by keeping it in contact with reservoirs in two ways :
(i) Sequentially keeping in contact with 2 reservoirs such that each reservoir supplies same amount of heat.
(ii) Sequentially keeping in contact with 8 reservoirs such that each reservoir supplies same amount of heat.
In both the cases body is brought from initial temperature 100°C to final temperature 200°C. Entropy change of the body in the two cases respectively is :
[2015]

Options:

A. ln2, 2ln2

B. 2ln2, 8ln2

C. ln2, 4ln2

D. ln2, ln2

Answer: D

Solution:

Solution:
The entropy change of the body

Question188

A gas is compressed from a volume of $2m^3$ to a volume of$1m^3$ at a constant pressure of 100 N/m^2 . Then it is heated at constant volume by supplying 150 J of energy. As a result, the internal energy of the gas:
[Online April 19, 2014]

Options:

A. increases by 250 J

B. decreases by 250 J

C. increases by 50 J

D. decreases by 50 J

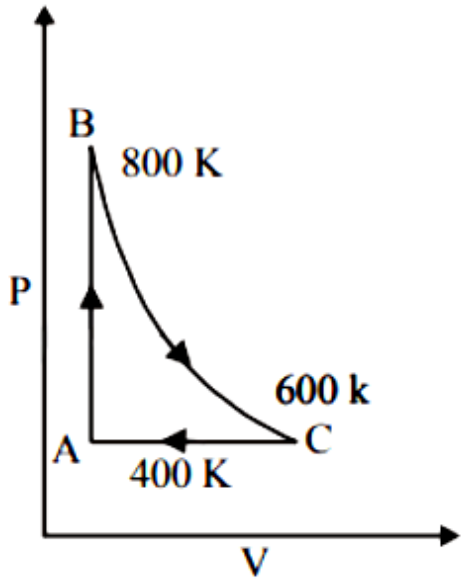
Answer: A

Solution:

Solution:
As we know,
$\Delta Q = \Delta u + \Delta w$ (Ist law of thermodynamics)
$\Rightarrow \Delta Q = \Delta u + P\Delta v$
or $150 = \Delta u + 100(1-2)$
$= \Delta u - 100$
$\therefore \Delta u = 150 + 100 = 250J$
Thus the internal energy of the gas increases by $250J$

Question189

One mole of a diatomic ideal gas undergoes a cyclic process ABC as shown in figure. The process BC is adiabatic. The temperatures at A, B and C are 400 K, 800 K and 600 K respectively. Choose the correct statement:



[2014]

Options:

A. The change in internal energy in whole cyclic process is 250 R.

B. The change in internal energy in the process CA is 700 R.

C. The change in internal energy in the process AB is - 350 R.

D. The change in internal energy in the process BC is – 500 R.

Answer: D

Solution:

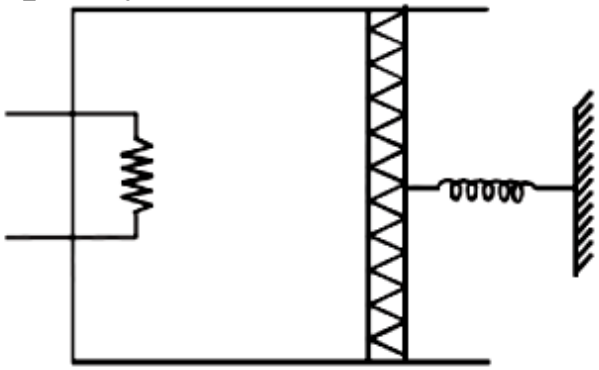
Solution:
In cyclic process, change in total internal energy is zero.
$\Delta U_{cyclic} = 0$
$\Delta U_{BC} = nC_v\Delta T = 1 \times \frac{5R}{2}\Delta T$
Where, $C_y =$ molar specific heat at constant volume.
For BC, $\Delta T = -200K$
$\therefore \Delta U_{BC} = -500R$

Question190

An ideal monoatomic gas is confined in a cylinder by a spring loaded piston of cross section $8.0 \times 10^{-3} m^2$. Initially the gas is at 300K and occupies a volume of $2.4 \times 10^{-3} m^3$ and the spring is in its relaxed state as shown in figure. The gas is heated by a small heater until the piston moves out slowly by 0.1m. The force constant of the spring is 8000N / m and the atmospheric pressure is $1.0 \times 10^5 N / m^2$. The cylinder and the piston are thermally insulated. The piston and the spring are massless and there is no friction between the piston and the cylinder. The final temperature of the gas will be:

(Neglect the heat loss through the lead wires of the heater. The heat

capacity of the heater coil is also negligible).



[Online April 11, 2014]

Options:

A. 300 K

B. 800 K

C. 500 K

D. 1000 K

Answer: C

Solution:

Solution:

Question191

During an adiabatic compression, 830J of work is done on 2 moles of a diatomic ideal gas to reduce its volume by 50%. The change in its temperature is nearly:
($R = 8.3 J\,K^{-1} mol^{-1}$)
[Online April 11, 2014]

Options:

A. 40 K

B. 33 K

C. 20 K

D. 14 K

Answer: C

Solution:

Solution:
Given : work done, $W = 830J$
No. of moles of gas, $\mu = 2$
For diatomic gas $\gamma = 1.4$
Work done during an adiabatic change

$$W = \frac{\mu R(T_1 - T_2)}{\gamma - 1}$$

$$\Rightarrow 830 = \frac{2 \times 8.3(\Delta T)}{1.4 - 1} = \frac{2 \times 8.3(\Delta T)}{0.4}$$

$$\Rightarrow \Delta T = \frac{830 \times 0.4}{2 \times 8.3} = 20K$$

Question192

The equation of state for a gas is given by $PV = nRT + \alpha V$, where n is the number of moles and alpha is a positive constant. The initial temperature and pressure of one mole of the gas contained in a cylinder are T_0 and P_0 respectively. The work done by the gas when its temperature doubles isobarically will be: [Online April 9, 2014]

Options:

A. $\frac{P_0 T_0 R}{P_0 - \alpha}$

B. $\frac{P_0 T_0 R}{P_0 + \alpha}$

C. $P_0 T_0 R \ln 2$

D. $P_0 T_0 R$

Answer: A

Solution:

Solution:

Question193

A Carnot engine absorbs 1000 J of heat energy from a reservoir at 127°C and rejects 600 J of heat energy during each cycle. The efficiency of engine and temperature of sink will be: [Online April 12, 2014]

Options:

A. 20% and – 43°C

B. 40% and – 33°C

C. 50% and – 20°C

D. 70% and – 10°C

Answer: B

Solution:

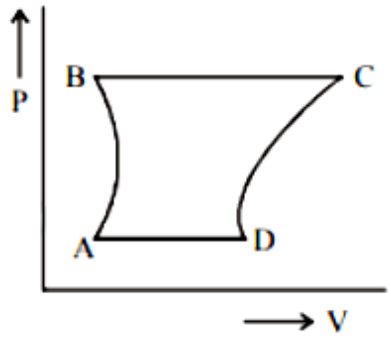
Solution:
Given :
$Q_1 = 1000J$
$Q_2 = 600J$
$T_1 = 127°C = 400K$
$T_2 = ?$
$\eta = ?$
Efficiency of carnot engine,
$\eta = \frac{W}{Q_1} \times 100\%$
or, $\eta = \frac{Q_2 - Q_1}{Q_1} \times 100\%$
or, $\eta = \frac{1000 - 600}{1000} \times 100\%$
$\eta = 40\%$
Now, for carnot cycle $\frac{Q_2}{Q_1} = \frac{T_2}{T_1}$
$\frac{600}{1000} = \frac{T_2}{400}$
$T_2 = 600 \times 4001000$
$= 240K$
$= 240 - 273$
$\therefore T_2 = -33°C$

Question194

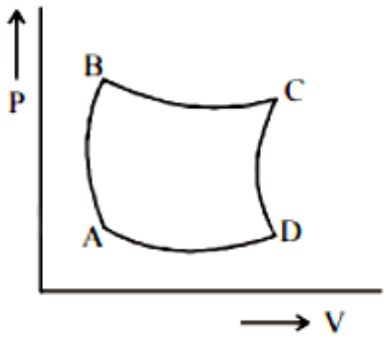
A certain amount of gas is taken through a cyclic process (A B C D A) that has two isobars, one isochore and one isothermal. The cycle can be represented on a P-V indicator diagram as :
[Online April 22, 2013]

Options:

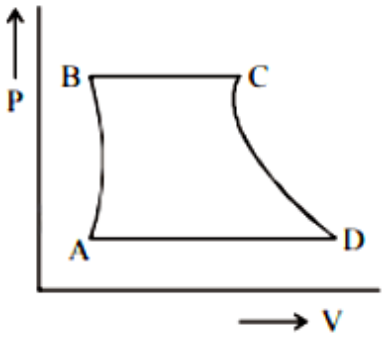
A.



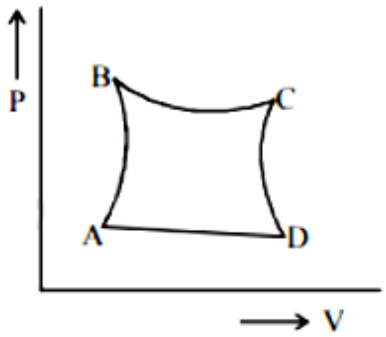
B.



C.



D.

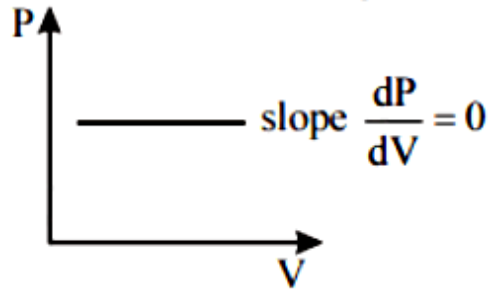


Answer: C

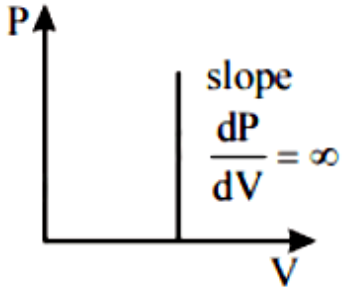
Solution:

Solution:

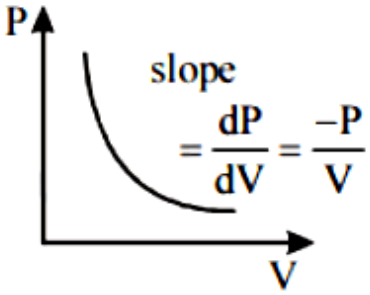
P-V indicator diagram for isobaric



P-V indicator diagram for isochoric process



P-V indicator diagram for isothermal process



Question195

An ideal gas at atmospheric pressure is adiabatically compressed so that its density becomes 32 times of its initial value. If the final

pressure of gas is 128 atmospheres, the value of 'γ' of the gas is : [Online April 22, 2013]

Options:

A. 1.5

B. 1.4

C. 1.3

D. 1.6

Answer: B

Solution:

Solution:

Volume of the gas $1v = \frac{m}{d}$ and

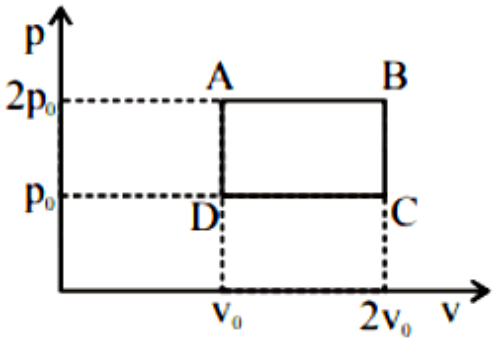
Using $PV^{\gamma} = \text{constant}$

$\frac{P'}{P} = \frac{V}{V'} = \left(\frac{d'}{d}\right)^{\gamma}$

or $128 = (32)^{\gamma}$

$\therefore \gamma = \frac{7}{5} = 1.4$

Question196



The above p-v diagram represents the thermodynamic cycle of an engine, operating with an ideal monatomic gas. The amount of heat, extracted from the source in a single cycle is [2013]

Options:

A. p_0v_0

B. $\left(\frac{13}{2}\right)p_0v_0$

C. $\left(\frac{11}{2}\right)p_0v_0$

D. $4p_0v_0$

Answer: B

Solution:

Solution:
Heat is extracted from the source in path DA and AB is

$$\Delta Q = \frac{3}{2}R\left(\frac{P_0V_0}{R}\right) + \frac{5}{2}R\left(\frac{2P_0V_0}{R}\right)$$

$$\Rightarrow \frac{3}{2}P_0V_0 + \frac{5}{2}2P_0V_0 = \left(\frac{13}{2}\right)P_0V_0$$

Question197

This question has Statement 1 and Statement 2. Of the four choices given after the Statements, choose the one that best describes the two Statements.

Statement 1: An inventor claims to have constructed an engine that has an efficiency of 30% when operated between the boiling and freezing points of water. This is not possible.

Statement 2: The efficiency of a real engine is always less than the efficiency of a Carnot engine operating between the same two temperatures.
[Online May 19, 2012]

Options:

A. Statement 1 is true, Statement 2 is true, Statement 2 is not the correct explanation of Statement 1.

B. Statement 1 is true, Statement 2 is false.

C. Statement 1 is false, Statement 2 is true.

D. Statement 1 is true, Statement 2 is true, Statement 2 is the correct explanation of Statement 1.

Answer: D

Solution:

Solution:
According to Carnot's theorem - no heat engine working between two given temperatures of source and sink can be more efficient than a perfectly reversible engine i.e. Carnot engine working between the same two temperatures.

Efficiency of Carnot's engine, $n = 1 - \frac{T_2}{T_1}$

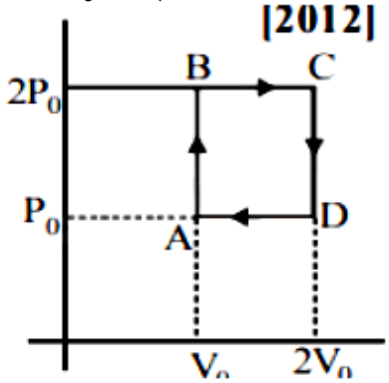
where, $T_1 =$ temperature of source

$T_2 =$ temperature of sink

Question198

Helium gas goes through a cycle ABCDA (consisting of two isochoric and isobaric lines) as shown in figure. The efficiency of this cycle is nearly : (Assume the gas to be close to ideal gas)

[2012]



[2012]

Options:

A. 15.4 %

B. 9.1 %

C. 10.5%

D. 12.5 %

Answer: A

Solution:

Solution:

The efficiency $\eta = \frac{\text{output work}}{\text{heat given to the system}}$

$= n\frac{3}{2}R\Delta T = \frac{3}{2}V_0\Delta P = \frac{3}{2}P_0V_0$

$W_i = \frac{n}{2}(P_0V_0) + \frac{n}{2}(2P_0V_0) + 2P_0V_0$

Heat given in going B to C $= nC_p\Delta T$

$= n\left(\frac{5}{2}R\right)\Delta T = \frac{5}{2}(2P_0)\Delta V$

$= 5P_0V_0$

and $W_0 =$ area under PV diagram P_0V_0

$\eta = \frac{W}{Q} = \frac{P_0V_0}{\frac{13}{2}P_0V_0} = \frac{2}{13}$

Efficiency in %

$\eta = \frac{2}{13} \times 100 = \frac{200}{13} \simeq 15.4\%$

Question199

An ideal monatomic gas with pressure P, volume V and temperature T is expanded isothermally to a volume 2V and a final pressure P_i. If the same gas is expanded adiabatically to a volume 2V , the final pressure is P_a. The ratio $\frac{P_a}{P_i}$ is

[Online May 26, 2012]

Options:

A. $2^{-1/3}$

B. $2^{1/3}$

C. $2^{2/3}$

D. $2^{-2/3}$

Answer: D

Solution:

Solution:

For isothermal process :

$PV = P_i2V$

$P = 2P_i$ .....(i)
For adiabatic process
$PV^{\gamma} = P_a(2V)^{\gamma}$
($\because$ for monatomic gas $\gamma = 5/3$)
or, $2P_1V^{\frac{5}{3}} = P_a(2V)^{\frac{5}{3}}$ [From (i)]
$\Rightarrow \frac{P_a}{P_i} = \frac{2}{2^{\frac{5}{3}}}$
$\Rightarrow \frac{P_a}{P_i} = 2^{\frac{-2}{3}}$

Question200

The pressure of an ideal gas varies with volume as P = αV , where α is a constant. One mole of the gas is allowed to undergo expansion such that its volume becomes ' m ' times its initial volume. The work done by the gas in the process is
[Online May 19, 2012]

Options:

A. $\frac{\alpha V}{2}(m^2 - 1)$

B. $\frac{\alpha^2 V^2}{2}(m^2 - 1)$

C. $\frac{\alpha}{2}(m^2 - 1)$

D. $\frac{\alpha V^2}{2}(m^2 - 1)$

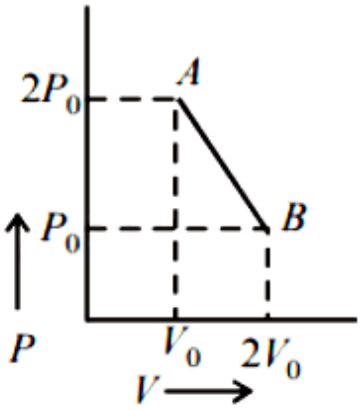
Answer: D

Solution:

Solution:
Given $P = \alpha V$
Work done, $w = \int_V^{mV} P\,dV$
$= \int_V^{mV} \alpha V\,dV = \frac{\alpha V^2}{2}(m^2 - 1).$

Question201

n moles of an ideal gas undergo a process A → B as shown in the figure. Maximum temperature of the gas during the process is



[Online May 12, 2012]

Options:

A. $\frac{9P_0V_0}{nR}$

B. $\frac{3P_0V_0}{2nR}$

C. $\frac{9P_0V_0}{2nR}$

D. $\frac{9P_0V_0}{4nR}$

Answer: B

Solution:

Solution:
Work done during the process A → B
= Area of trapezium (= area bounded by indicator diagram with V-axis)

$$= \frac{1}{2}(2P_0 + P_0)(2V_0 - V_0) = \frac{3}{2}P_0V_0$$

Ideal gas eqn : $PV = nRT$

$$\Rightarrow T = \frac{PV}{nR} = \frac{3P_0V_0}{2nR}$$

Question202

This question has Statement 1 and Statement 2. Of the four choices given after the Statements, choose the one that best describes the two Statements.

Statement 1: In an adiabatic process, change in internal energy of a gas is equal to work done on/by the gas in the process.

Statement 2: The temperature of a gas remains constant in an adiabatic process.
[Online May 7, 2012]

Options:

A. Statement 1 is true, Statement 2 is true, Statement 2 is a correct explanation of Statement 1.

B. Statement 1 is true, Statement 2 is false

C. Statement 1 is false, Statement 2 is true.

D. Statement 1 is false, Statement 2 is true, Statement 2 is not a correct explanation of Statement 1.

Answer: B

Solution:

Solution:
In an adiabatic process, $\delta H = 0$
And according to first law of thermodynamics
$\delta H = \delta U + W$
$\therefore W = -\delta U$

Question203

A Carnot engine, whose efficiency is 40%, takes in heat from a source maintained at a temperature of 500K. It is desired to have an engine of efficiency 60%. Then, the intake temperature for the same exhaust (sink) temperature must be :
[2012]

Options:

A. efficiency of Carnot engine cannot be made larger than 50%

B. 1200 K

C. 750 K

D. 600 K

Answer: C

Solution:

Solution:
The efficiency of the carnot's heat engine is given as

$$\eta = \left(1 - \frac{T_2}{T_1}\right) \times 100$$

When efficiency is 40%,

$$T_1 = 500K \; ; \; \eta = 40$$

$$40 = \left(1 - \frac{T_2}{500}\right) \times 100$$

$$\Rightarrow \frac{40}{100} = 1 - \frac{T_2}{500}$$

$$\Rightarrow \frac{T_2}{500} = \frac{60}{100} \Rightarrow T_2 = 300K$$

When efficiency is 60%, then

$$\frac{60}{100} = \left(1 - \frac{300}{T_2}\right) \Rightarrow \frac{300}{T_2} = \frac{40}{100}$$

$$\Rightarrow T_2 = \frac{100 \times 300}{40} \Rightarrow T_2 = 750K$$

Question204

The door of a working refrigerator is left open in a well insulated room. The temperature of air in the room will [Online May 26, 2012]

Options:

A. decrease

B. increase in winters and decrease in summers

C. remain the same

D. increase

Answer: D

Solution:

Solution:
In a refrigerator, the heat dissipated in the atmosphere is more than that taken from the cooling chamber, therefore the room is heated. If the door of a refrigerator is kept open.

Question205

A container with insulating walls is divided into equal parts by a partition fitted with a valve. One part is filled with an ideal gas at a pressure P and temperature T, whereas the other part is completly evacuated. If the valve is suddenly opened, the pressure and temperature of the gas will be : [2011 RS]

Options:

A. $\frac{P}{2}, \frac{T}{2}$

B. P, T

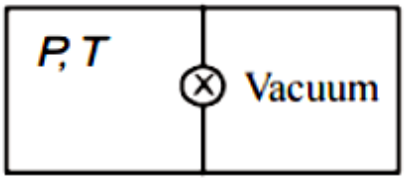
C. P, $\frac{T}{2}$

D. $\frac{P}{2}$, T

Answer: D

Solution:

Solution:



It is the free expansion
∴ So, T remains constant
$\Rightarrow P_1V_1 = P_2V_2$
$\Rightarrow P\frac{V}{2} = P_2(V)$
$P_2 = \left(\frac{P}{2}\right)$

Question206

A Carnot engine operating between temperatures T_1 and T_2 has efficiency $\frac{1}{6}$. When T_2 is lowered by 62K its efficiency increases to $\frac{1}{3}$. Then T_1 and T_2 are, respectively:
[2011]

Options:

A. 372 K and 310 K

B. 330 K and 268 K

C. 310 K and 248 K

D. 372 K and 310 K

Answer: D

Solution:

Solution:
Efficiency of engine

$$\eta_1 = 1 - \frac{T_2}{T_1} = \frac{1}{6}$$

$$\Rightarrow \frac{T_2}{T_1} = \frac{5}{6} \text{ .....(i)}$$

When T_2 is lowered by $62K$, then

Again, $\eta_2 = 1 - \frac{T_2 - 62}{T_1}$

$$= 1 - \frac{T_2}{T_1} + \frac{62}{T_1} = \frac{1}{3} \text{ .....(ii)}$$

Solving (i) and (ii), we get,

$T_1 = 372K$ and $T_2 = \frac{5}{6} \times 372 = 310K$

Question207

A diatomic ideal gas is used in a Carnot engine as the working substance. If during the adiabatic expansion part of the cycle the volume of the gas increases from V to 32 V, the efficiency of the

engine is
[2010]

Options:

A. 0.5

B. 0.75

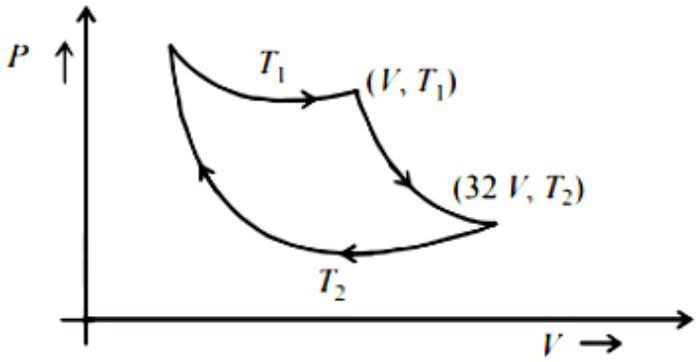
C. 0.99

D. 0.25

Answer: B

Solution:

Solution:



For adiabatic expansion $T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$

$\Rightarrow T_1V^{g-1} = T_2(32V)^{g-1}$

$\Rightarrow \frac{T_1}{T_2} = (32)^{\gamma-1}$

For diatomic gas, $\gamma = \frac{7}{5}$

$\therefore \gamma - 1 = \frac{2}{5}$

$\therefore \frac{T_1}{T_2} = (32)^{\frac{2}{5}} \Rightarrow T_1 = 4T_2$

Now, efficiency $= 1 - \frac{T_2}{T_1}$

$= 1 - \frac{T_2}{4T_2} = 1 - \frac{1}{4} = \frac{3}{4} = 0.75.$

Question208

Assuming the gas to be ideal the work done on the gas intaking it from A to B is
[2009]

Options:

A. 300 R

B. 400 R

C. 500 R

D. 200 R

Answer: B

Solution:

Solution:
The process A → B is isobaric.
∴ work done $W_{AB} = nR(T_2 - T_1)$
$= 2R(500 - 300) = 400R$

Question209

The work done on the gas in taking it from D to A is
[2009]

Options:

A. + 414 R

B. – 690 R

C. + 690 R

D. – 414 R

Answer: A

Solution:

Solution:

The process D to A is isothermal as temperature is constant.

Work done, $W_{DA} = 2.303nRT \log_{10}\frac{P_D}{P_A}$

$= 2.303 \times 2R \times 300$

$\log_{10}\frac{1 \times 10^5}{2 \times 10^5} - 414R$

Therefore, work done on the gas is +414R.

Question210

The net work done on the gas in the cycle ABCDA is [2009]

Options:

A. 279 R

B. 1076 R

C. 1904 R

D. zero

Answer: A

Solution:

Solution:

The net work in the cycle ABCDA is

$W = W_{AB} + W_{BC} + W_{CD} + W_{DA}$

$= 400R + 2.303nRT \log\frac{P_B}{P_C} + (-400R) - 414R$

$= 2.303 \times 2R \times 500 \log\frac{2 \times 10^5}{1 \times 10^5} - 414R$

$= 693.2R - 414R = 279.2R$

Question211

An insulated container of gas has two chambers separated by an insulating partition. One of the chambers has volume V_1 and contains ideal gas at pressure P_1 and temperature T_1. The other chamber has volume V_2 and contains ideal gas at pressure P_2 and

temperature T_2. If the partition is removed without doing any work on the gas, the final equilibrium temperature of the gas in the container will be
[2008]

Options:

A. $\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_2+P_2V_2T_1}$

B. $\frac{P_1V_1T_1+P_2V_2T_2}{P_1V_1+P_2V_2}$

C. $\frac{P_1V_1T_2+P_2V_2T_1}{P_1V_1+P_2V_2}$

D. $\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_1+P_2V_2T_2}$

Answer: A

Solution:

Solution:
Here $Q=0$ and $W=0$. Therefore from first law of thermodynamics $\Delta U=Q+W=0$
Internal energy of first vessle + Internal energy of second vessel = Internal energy of combined vessel

$$n_1C_vT_1+n_2C_vT_2=(n_1+n_2)C_vT$$

$$\therefore T=\frac{n_1T_1+n_2T_2}{n_1+n_2}$$

For first vessel $n_1=\frac{P_1V_1}{RT_1}$ and for second vessle $n_2=\frac{P_2V_2}{RT_2}$

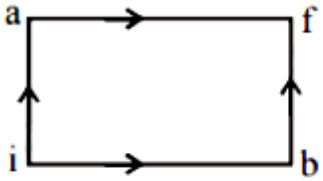
$$\therefore T=\frac{\frac{P_1V_1}{RT_1}\times T_1+\frac{P_2V_2}{RT_2}\times T_2}{P_1V_1RT_1+\frac{P_2V_2}{RT_2}}$$

$$=\frac{T_1T_2(P_1V_1+P_2V_2)}{P_1V_1T_2+P_2V_2T_1}$$

Question212

When a system is taken from state i to state f along the path iaf, it is found that Q = 50 cal and W = 20 cal. Along the path ibf Q = 36 cal.

W along the path ibf is



[2007]

Options:

A. 14 cal

B. 6 cal

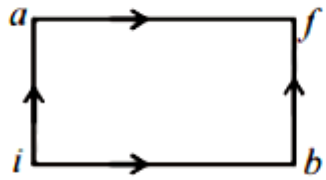
C. 16 cal

D. 66 cal

Answer: B

Solution:

Solution:



(b) For path iaf,
$Q_1 = 50\text{cal}$, $W_1 = 20\text{cal}$
By first law of thermodynamics,
$\Delta U = Q_1 - W_1 = 50 - 20 = 30\text{cal}$
For path ibf
$Q_2 = 36\text{cal}$
$W_2 = ?$
$\Delta U_{ibf} = Q_2 - W_2$
Since, the change in internal energy does not depend on the path, therefore $\Delta U_{iaf} = \Delta U_{ibf}$
$\Delta U_{iaf} = \Delta U_{ibf}$
$\Rightarrow 30 = Q_2 - W_2$
$\Rightarrow W_2 = 36 - 30 = 6$ cal.

Question213

A Carnot engine, having an efficiency of $\eta = 1/10$ as heat engine, is used as a refrigerator. If the work done on the system is 10 J, the

amount of energy absorbed from the reservoir at lower temperature is
[2007]

Options:

A. 100 J

B. 99 J

C. 90 J

D. 1 J

Answer: C

Solution:

Solution:
The efficiency (η) of a Carnot engine and the coefficient of performance (β) of a refrigerator are related as

$\beta = \frac{1-\eta}{\eta}$

Also, $\beta = \frac{Q_2}{W}$

$\therefore \beta = \frac{1-n}{n} = \frac{Q_2}{W}$

$\therefore \beta = \frac{1-\frac{1}{10}}{\left(\frac{1}{10}\right)} = \frac{Q_2}{W}$

is independent of path taken by the process.

$\Rightarrow 9 = \frac{Q_2}{10}$

$\Rightarrow Q_2 = 90J$.

Question214

The work of 146 kJ is performed in order to compress one kilo mole of gas adiabatically and in this process the temperature of the gas increases by 7°C. The gas is
$(R = 8.3J\ mol^{-1}K^{-1})$
[2006]

Options:

A. diatomic

B. triatomic

C. a mixture of monoatomic and diatomic

D. monoatomic

Answer: A

Solution:

Solution:
Work done in adiabatic compression is given by

$$W = \frac{nR\Delta T}{1-\gamma}$$

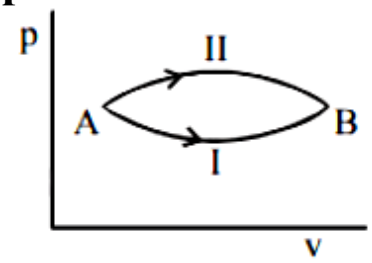
$$\Rightarrow -146000 = \frac{1000 \times 8.3 \times 7}{1-\gamma}$$

or $1-\gamma = -\frac{58.1}{146} \Rightarrow \gamma = 1 + \frac{58.1}{146} = 1.4$

Hence the gas is diatomic.

Question215

A system goes from A to B via two processes I and II as shown in figure. If ΔU_1 and ΔU_2 are the changes in internal energies in the processes I and II respectively, then



[2005]

Options:

A. relation between ΔU_1 and ΔU_2 can not be determined

B. $\Delta U_1 = \Delta U_2$

C. $\Delta U_2 < \Delta U_1$

D. $\Delta U_2 > \Delta U_1$

Answer: B

Solution:

Solution:
Change in internal energy is independent of path taken by the process. It only depends on initial and final states i.e.,
$\Delta U_1 = \Delta U_2$

Question216

Which of the following is incorrect regarding the first law of thermodynamics?
[2005]

Options:

A. It is a restatement of the principle of conservation of energy

B. It is not applicable to any cyclic process

C. It does not introduces the concept of the entropy

D. It introduces the concept of the internal energy

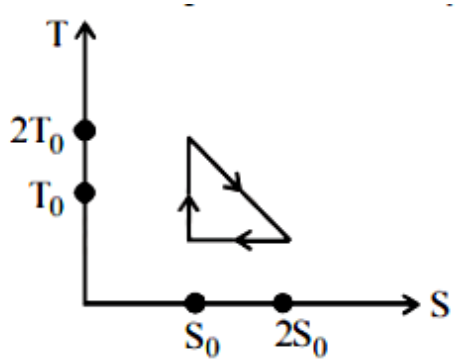
Answer: 0

Solution:

Solution:
First law is applicable to a cyclic process. Concept of entropy is introduced by the second law of thermodynamics.

Question217

The temperature-entropy diagram of a reversible engine cycle is given in the figure. Its efficiency is



[2005]

Options:

A. $\frac{1}{4}$

B. $\frac{1}{2}$

C. $\frac{2}{3}$

D. $\frac{1}{3}$

Answer: D

Solution:

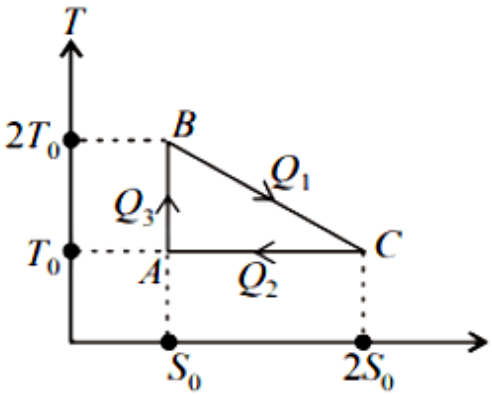
Solution:

$Q_1 =$ area under $BC = T_0S_0 + \frac{1}{2}T_0S_0$

$Q_2 =$ area under $AC = T_0(2S_0 - S_0) = T_0S_0$

and $Q_3 = 0$

Efficiency, $\eta = \frac{W}{Q_1} = \frac{Q_1 - Q_2}{Q_1}$



$= 1 - \frac{Q_2}{Q_1} = 1 - \frac{T_0S_0}{\frac{3}{2}T_0S_0} = \frac{1}{3}$

Question218

Which of the following statements is correct for any thermodynamic system ?
[2004]

Options:

A. The change in entropy can never be zero

B. Internal energy and entropy are state functions

C. The internal energy changes in all processes

D. The work done in an adiabatic process is always zero.

Answer: B

Solution:

Solution:
Internal energy and entropy are state function, they are independent of path taken.

Question219

Which of the following parameters does not characterize the thermodynamic state of matter?
[2003]

Options:

A. Temperature

B. Pressure

C. Work

D. Volume

Answer: C

Solution:

Solution:

Work is not a state function. The remaining three parameters are state function.

Question220

“Heat cannot by itself flow from a body at lower temperature to a body at higher temperature” is a statement or consequence of [2003]

Options:

A. second law of thermodynamics

B. conservation of momentum

C. conservation of mass

D. first law of thermodynamics

Answer: A

Solution:

Solution:
This is a consequence of second law of thermodynamics

Question221

A Carnot engine takes 3×10^6 cal of heat from a reservoir at 627°C, and gives it to a sink at 27°C. The work done by the engine is [2003]

Options:

A. 4.2×10^6J

B. 8.4×10^6J

C. 16.8×10^6J

D. zero

Answer: B

Solution:

Solution:
Here, $T_1 = 627 + 273 = 900K$
$T_2 = 27 + 273 = 300K$
Efficiency, $\eta = 1 - \frac{T_2}{T_1}$
$= 1 - \frac{300}{900} = 1 - \frac{1}{3} = \frac{2}{3}$
But $\eta = \frac{W}{Q}$
$\therefore \frac{W}{Q} = \frac{2}{3} \Rightarrow W = \frac{2}{3} \times Q = \frac{2}{3} \times 3 \times 10^6$
$= 2 \times 10^6 \text{ cal}$
$= 2 \times 10^6 \times 4.2J = 8.4 \times 10^6 J$

Question222

Which statement is incorrect?
[2002]

Options:

A. All reversible cycles have same efficiency

B. Reversible cycle has more efficiency than an irreversible one

C. Carnot cycle is a reversible one

D. Carnot cycle has the maximum efficiency in all cycles

Answer: A

Solution:

Solution:
All reversible engines have same efficiencies if they are working for the same temperature of source and sink.
If the temperatures are different, the efficiency is different.

Question223

Even Carnot engine cannot give 100% efficiency because we cannot
[2002]

Options:

A. prevent radiation

B. find ideal sources

C. reach absolute zero temperature

D. eliminate friction

Answer: C

Solution:

Solution:
In Carnot's cycle we assume frictionless piston, absolute insulation and ideal source and sink (reservoirs).

The efficiency of carnot's cycle $\eta = 1 - \frac{T_2}{T_1}$

The efficiency of carnot engine will be 100% when its $\text{sink}(T_2)$ is at 0K.

The temperature of 0K (absolute zero) cannot be realised in practice so, efficiency is never 100%.